

METAL PROGRESS

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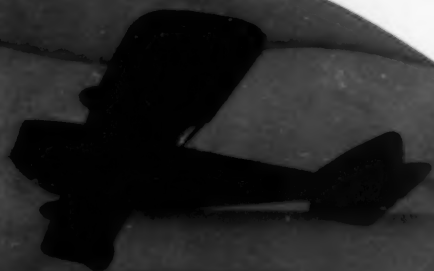
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Metal Progress

METALLURGY — LIABILITY OR ASSET?

THE CONDITION of the departments in a manufacturing plant over which the Metallurgist usually has control—heat treatment, electroplating and finishing, laboratory—are more the result of what the general manager *thinks* about metallurgy than what he *knows* about it. If he looks upon heat treatment as something that has to be endured because it can't be cured, then it is sure to be done in the most undesirable corner in the factory, where some forgotten men are endeavoring to do a decent job with furnaces and tools that may date back to before the Great War. On the other hand, if the manager is convinced that modern metallurgy is putting into his product some desirable refinements, some essential qualities he could get in no other way, then the heat treatment department, the plating and finishing department, and the control laboratory will be fit places to work in, and the tools and equipment will compare favorably with the best.

It is no accident, either, that in such well-managed factories all the other departments, warehouse, forge, machine, assembly, shipping, have the best available equipment. In fact, it is these successful industries, and outstanding units in others, that have developed the best of modern machine tools and heat treatment operations. Their top men realized the need, and either led the way in their design and construction, or cooperated whole-heartedly with the tool, furnace and equipment builders in making the advances, step by step, that have led to their present excellence. It is likewise no accident that these same plants have insisted on correct cost accounting—they *know* what the various operations cost, and are able to tell promptly whether an "improvement" is really reducing the net over-all costs.

A man who has an idea that can be translated into a manufacturing economy therefore goes first to the firms that have least to gain by it. Paradoxical though that may seem, he

knows he will get a better hearing and a fairer trial in a plant where the chances of cost cutting are on the order of cents or mills per piece, than in one where the possibilities are measured in dimes or dollars. It is likely, in the first place, that the management of the latter factory does not know what its exact costs are, and in the second place, it has for a long time been inhospitable to new ideas.

For these backward managements the problem is education, and this is a tedious job. Fortunately they do not need to become scientific metallurgists or expert accountants; as pointed out at the outset, what they need to know is *what* modern metallurgy can do for them, rather than the details of *how* or *why* it does it.

Even the dullest of the conservatives knows that a foundry is necessary to convert pig metal into usable forms and that a machine shop is necessary to convert these usable forms into salable hardware. Foundry and machine shop are no more necessary evils than a man's hands are necessary evils, but instruments of unimaginable capabilities. Modern metallurgy is of the same nature. It has given the designer and constructing engineer a wealth of materials from which something of correct inherent properties can be selected. It has given the foundry, forge and machine shop methods whereby castability, workability, and machinability of such alloys can be improved to the maximum. Finally, the semi-finished part can be given suitable wear resistance or corrosion resistance or impact resistance or eye appeal through the efforts of heat treater, plater, finisher and inspector.

From these essential operations come parts and machines *procurable in no other way*. It is the best way, and, as in all things, the best way will be found to be the cheapest—a proposition requiring no argument among those who know their costs.



By Francis G. Jenkins
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General machinability of copper alloys

LITTLE THOUGHT has been directed to the machining of copper alloys at average speed possibly because brass, the ordinary copper alloy, may usually be machined without too much trouble, and because free-cutting brass may be employed for intricate machining. Thus it follows that the complete effect of microstructure, hardness and the addition of lead to brass and bronze, with respect to general machinability, is often not entirely comprehended and consequently not utilized to best advantage. This particularly applies, for example, when we observe the needlessly large quantities of lead, supposedly added to improve machinability, in many complex cast brass and bronze compositions still so prevalent today. It is universally recognized that lead included for the purpose of promoting general machinability may be held to a reasonably low figure and thus eliminate any deleterious effects of the larger additions.

By combining the most favorable conditions of (a) tool design, (b) alloy, (c) microstructure, and (d) hardness or amount of cold drawing, and incorporating whenever possible the refinements utilized in free-machining brasses, the general machinability of the common copper alloys may be considerably improved. By "general machinability" is meant machining at average cutting speeds and feeds with satisfactory finish and tool life.

Tool Shape — It is noted in the beginning that tool shape, tool material and working speed are extremely important and correlated factors in successful machining. Brass ranging in hardness from soft yellow brass to medium hard brass is generally turned with tools having little or no rake, because the chip has low friction and tenacity. For the same reason lubrication and cooling are unnecessary and a large tool angle increases the strength of the cutting edge, as pointed out by P. W. Blair in the June

1927 issue of *Metal Industry*, in an article entitled "The Machining of Special Bronzes." Abrasion, however, increases and for this reason a higher degree of tool hardness is advisable. Medium high speeds and fine feeds are used and the tools must be kept sharp by frequent grinding to obtain best results.

It is important, on the other hand, that sufficient top rake be given to the cutting tool on manganese bronze, phosphorus bronze, and on many alpha solutions of copper with tin, silicon, or aluminum. Due to their strength and hardness these alloys are tougher than the ordinary brass in machining. Here the resistance to bending and fracture is high, and considerable heat is generated by the friction of the chip. These materials are machined with cutting tools of heavy sections similar to those used for steel, and require efficient lubrication to carry away the heat and reduce friction. High speed steel has a real advantage over carbon steel for machining these tough metals.

Microstructure of Alloy — While the machinability of copper is poor because of its high ductility and low hardness, the addition of zinc alone up to 35% does not increase the ease of machining. Hardness and strength both increase with progressive additions of zinc, as also does the ductility. Machinability of steel, at least, depends on two main factors, low ductility and low strength — in the opinion of

J. D. Armour, quoted in an anonymous article on "Some Factors Affecting the Machinability of Steels and Other Alloys" in METAL PROGRESS for January 1936. Everything else remaining equal, this is probably true for the copper alloys as well, the machinability decreasing on increase in zinc content.

However, at 65% copper, 35% zinc, further additions of zinc introduce the hard beta constituent into the microstructure which interrupts the continuity of the alpha crystals and renders the alloy quite machinable. It is widely believed and often stated that a discontinuous structure tends to facilitate machining, for the chips are easily broken up and removed.

With a small amount of beta constituent well distributed (that is, a brass with 60 to 63% copper) machinability is best improved. As the proportion of beta content increases, the strength rapidly rises which in turn increases the energy required for cutting and the tendency of the beta to break up the alpha structure is defeated.

The grain size is a vital factor and, particularly with alpha-beta brass, should be kept small for best results.

The addition of iron to alpha brass or alpha-beta brass, even to the extent of 3 or 4%, should show little or no effect on general machinability, though the addition of tin or aluminum will harden the structure and slightly slow up machining.

In alpha copper-tin alloys in the cast form a peculiar structural condition prevails that facilitates machining. Chiefly because of the wide freezing range of all cast bronzes, opportunity is given for the formation of interdendritic shrinkage cavities and also for the evolution of gas into microscopic gas pockets. The presence of this intercrystalline unsoundness serves to produce small chips and renders the castings quite machinable.

Effect of Cold Working—Cold working increases the energy required to cut brass rod and it is for this reason, perhaps, that annealed rod *drills* better. However, soft metal cannot be cut efficiently unless perfectly supported; this is possible in straight drilling. The soft rod will bend away from a side-cutting tool and chattering, digging in, non-uniformity and short tool life will result. Thus, as Crampton puts it, a hard rod performs better than a soft rod not due to superior cutting properties of the former, but rather to the fact that a harder, stiffer rod stands up against the tool better, resulting in an

apparent improvement in machinability. (D. K. Crampton and H. P. Croft discuss the machinability of copper alloys in *Handbook*, page 1130, and in articles in METAL PROGRESS, May 1931, January 1933 and January 1936.)

Cold work of alpha-beta brass introduces a factor considered important by many, namely a "fibrous" structure, that appears to enhance the machinability. In stampings and castings the alpha and beta constituents are possessed of no definite orientation. In rod it is noted, however, that the crystallites are arranged parallel to the axis in the direction of rolling. It has been shown that such an arrangement of fine alpha crystals, separated by a comparatively small quantity of beta, is the most desirable for machining purposes.

Effect of Lead Additions—As has been pointed out, copper and the homogeneous alpha brasses are not easily machined, because long spiral turnings clutter-up and foul a close tool setting. Machinability is improved by adding an insoluble constituent to break up the metal continuity and produce short chips. While selenium and tellurium have been employed, the customary alloy addition is lead. It exists as small globules scattered through the metal.

Even though it is felt necessary to obtain extreme ease of machinability, the lead content need not range more than 1.5% for the 98% copper alloy to approximately 2% for the high brasses. Below 61% copper, little or no lead is

Photo by Irving Browning



required because of the introduction of the hard beta constituent with its ability to aid machining. According to Alan Morris ("Machinability of Free-Cutting Brass Rod," *Transactions A.I.M.E.* 1932, page 323) the machinability of Muntz metal improves rapidly with small additions of lead but much less rapidly as the lead content increases. This is essentially true of all copper alloys. In experiments by Morris, the addition of 0.62% lead to Muntz metal, 60-40 brass, decreased the power required to machine by 46% while the addition of 3.43% lead only decreased the power by 60.5%.

This is further true in the case of alpha copper-tin castings; little effect is produced by adding more than but a small amount of lead. For instance, Lewis H. Fawcett states in *Metals Handbook*, page 1089, that 0.50% lead in gun metal (88-10-2 and 88-8-4 Cu-Sn-Zn) will make the alloy free-cutting and more than this does not give proportional improvement in the machinability.

Too often brasses and bronzes for general purposes are absurdly complex and among other things contain up to 5 and 10% lead because they may require considerable machining, intricate or otherwise. For many years even producers of copper alloys seemed to have considered that the only way to obtain readily machinable alloys was to incorporate lead in as great a percentage as the size of the ingot and proportion of other elements would permit. This is poor policy for other reasons than that only relatively small amounts are necessary for good machining properties.

The addition of lead to brass should be carefully controlled, for in large quantities it will lower many properties including strength, ductility, impact, high temperature properties and even pressure tightness.

Lead, because of the facility with which fracture passes through the globules, is beneficial in brass requiring excessive shearing or blanking (especially in heavy sections) as it results in a cut which is quite smooth and free from burr. For this very reason, namely its weakening of the metal structure, its presence must be kept to a low minimum to maintain the metal's superior physical properties.

The common analysis of 3.5% lead in a 61.5-35 Cu-Zn alloy is really a free-cutting, screw machine alloy possessing a specific combination of properties which makes it peculiarly adapted to use in the highly intricate screw machines. Here it is obvious that, for

maximum production, chips must be small and fall away from the tool readily to prevent fouling. However, it should be emphasized that the suitability of a material for screw machine production is not necessarily a criterion of its *general* machinability. The brass 60% copper, 1% tin, 0.5% lead, remainder zinc is an alloy with all-round better properties than the corresponding screw machine composition, and for general lathe machining is on a par with the latter even though it is not free-cutting.

Thus, it is concluded that for intricate machining operations at average cutting speeds, many copper alloys with little or no lead are eminently satisfactory, making it quite unnecessary to resort to free-machining compositions.

Since lead melts at 621° F. all leaded brasses are rendered hot-short and the improved machinability is obtained with sacrifice of hot-working properties. According to D. Bunting in an article on "The Influence of Lead and Tin on the Brittle Ranges of Brass," in *Journal of the Institute of Metals*, 1925, page 97, lead is to be avoided in apparatus working at high temperatures because of the facility with which lead segregates to the grain boundary, increasing the brittle range. The alpha and the beta alloys are affected much more than the alpha-beta. It is universally recognized that 70-30 brass which is to be hot-rolled with safety must be free from lead.

It is noted that lead is usually less than 0.5% in cast bronzes required to withstand severe hydraulic and steam pressure, the reason being that the presence of lead definitely causes porosity. Defective compositions in point include "hydraulic bronze" (85 Cu, 5 Zn, 5 Sn, 5 Pb) and a variety of leaded gun metals, all of which are inferior, as regards pressure tightness, to the lead-free gun metal (88 Cu, 8 Sn, 4 Zn).

Summarizing: For general, average speed machining, the presence of lead is not always necessary nor desirable and should be kept down to a reasonably low figure. It is to be avoided especially in connection with applications requiring superior physical properties or pressure tightness and for apparatus working at elevated temperature.

Though the deleterious effect of the presence of lead in brass has long been thought for many purposes to be of little consequence, in this present age of scientific alloys and of precise metallurgical control there is little excuse for tolerating harmful constituents.

By Albert F. Stuebing
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New York

High tensile steels for light weight construction

A PRINCIPLE which engineers and metallurgists were taught until recently was as follows: "Alloying elements in steels are not a practical means of improving physical properties unless the material is to be heat treated." It is therefore significant that numerous high strength steels containing relatively low percentages of the most familiar alloying elements have been extensively applied in many industries *without* heat treatment. These are low cost, tonnage steels made by the openhearth process. They possess high physical properties as they come from the rolling mills and would not fulfill their purpose if heat treatment were required. Some of them also have enhanced corrosion resistance.

These "high tensile steels" or "high yield strength steels" have been such an important factor in the recent development of light weight construction that they are frequently referred to, even by prominent engineers, as "light weight steels," despite the knowledge that specific gravity is unchanged.

This new development in industry is sometimes regarded with suspicion by conservatives. They view it as a heroic struggle for weight

reduction at the cost of strength or durability. This is a gross misconception. Designers have found that, by the use of high tensile steel and its proper disposition, equipment and structures can be made substantially lighter and still provide equal or greater strength to withstand applied forces and impacts of service. Gratifying economies in operation are therefore achieved without any increase in maintenance or depreciation and often with no increase in first cost.

The basic features of the new light weight development are best illustrated by the transportation

industry. High speed trains on western railroads afford excellent examples of this advance in passenger equipment. Cars in the "Daylight" trains of the Southern Pacific weigh 30% less than the equipment they replaced, and this has been the principal factor in shortening the time between Los Angeles and San Francisco from 11 hr. to 9¾ hr. Cars for the "Hiawatha" of the Milwaukee railroad, made of steel having high tensile and corrosion resisting properties, replaced light weight welded cars of carbon steel, with further reduction of 17% in weight. A train of nine cars is now hauled by the same locomotive at the same speed and with the same amount of fuel as seven of the older ones. Weight was reduced principally in the body structure; for instance, in the coaches, the car body was reduced 22.3%, or from 72,200 lb. to 56,100 lb.

A most recent illustration is the streamlining of the "20th Century" and the "Broadway Limited," with mile-a-minute schedules between Chicago and New York. Altogether 114 new cars were required, in which high tensile, corrosion resistant steels were extensively used. Stainless steel, itself a high tensile steel, was

Somewhat condensed from a paper read at Western Metal Congress

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used for decorative trim and kitchen equipment, and for some of the dining car bodies. Approximately one third the weight of a conventional train of Pullman cars is saved, and a fuel saving of 10 to 15% is anticipated, despite the increased speed.

Such developments have not been limited to high speed equipment, nor to American railroads. The New Haven railroad alone has some 205 coaches made of the new steels; in them about 36,000 lb. or 26% of the weight is saved by high tensile steel. Thickness is reduced in center sills, side sheets, side posts, belt rails, etc., some parts being only half as thick as necessary in carbon steel.

In all, well over 1200 rail units made of high strength steel are now in passenger service in America. Railroads in other countries favor steel underframes and wood superstructures, because the increased weight of all-steel cars is considered a serious handicap. By using these new steels, the safety of all-steel construction

is secured without exceeding the weight of composite equipment, as in the trains recently built by the Victorian Government Railways.

From an economic standpoint, the freight car is much more important, because there are 50 of them for every passenger car on American railroads. The president of the Burlington railroad, Ralph Budd, recently said: "The handling of freight cars alone, not counting their contents, produces about 500 billion ton-miles of transportation in a year. It is entirely practicable, if the money were available, to reduce the weight of freight cars by one fourth, which would mean a reduction of 125 billion ton-miles in the movement of cars alone, in a year. At the very low allowance of one mill per ton-mile, this would save about \$125,000,000 a year."

A new all-welded box car built of high tensile steel illustrates the statements made by Mr. Budd. This car is five tons lighter than the A.A.R. standard car, which is itself an efficient, highly developed design. The Engineering Research Division of the Association of American Railroads conducted collision-impact tests of cars of these two types loaded to full capacity, so that each weighed 169,000 lb. Stresses at many locations in both cars were determined by strain gages. This new car, despite its lighter weight and five tons additional lading, withstood higher speeds in impact without distortion of the members than did the standard car.

Many noteworthy designs of freight cars have been prepared to utilize high tensile steels. Their advantages are indicated by the fact that within three years they have been used in more than 16,000 freight cars.

In the matter of highway transportation, automotive designers have long devoted careful study to the proper selection of materials and to reduction of weight. Nevertheless, further weight saving is being accomplished in trucks and buses, particularly gasoline tank trucks. High strength combined with ductility and weldability in medium gage sheets saves as much as 2½ tons when compared to tank trucks and semi-trailers constructed of plain steel. Safety and serviceability are increased, due to better resistance to corrosion and increased ability to withstand severe impacts without puncturing.

Welded Frame for One of the Cars for Southern Pacific "Daylight" Trains, in Which Welded High Tensile Steel Body Structure Is a Large Factor in Saving 30% of the Dead Load



Marine Applications

The same economic considerations apply to water transportation, although the factors vary widely depending on the class of service.

In oil tankers, corrosion is serious. Several installations of high tensile steel have been made in such vessels. Their precise life in comparison with that of plain steel ships cannot be determined definitely because the first application has been in service only three years, but the trend is now predictable. That there will be a substantial increase in service life is obvious. Careful corrosion tests have shown that one new high tensile, corrosion resisting steel, when exposed alternately to gasoline, sea water and moist air, has one third to one half longer life than plain carbon or copper steel. When exposed to flowing sea water or when kept constantly in motion in aerated hot municipal water, the life of this same high tensile steel is found to be two to four times that of plain steel.

Mining Equipment and Structures

In mine cars, high strength and ability to withstand impacts and to resist corrosive conditions are necessary. In elevator cages and skips, reduction in dead weight increases the loads that can be hoisted and brings substantial economies, especially in deep mines. Chutes, screens and dredge pipe are made of this and other steels in this group, relatively high in manganese, with high abrasion resistance.

A striking example is found in a large electric power shovel used for stripping overburden. This shovel carries a 30-cu.yd. dipper on a "stick" 70 ft. long and a 106-ft. boom. It incorporates high tensile, medium manganese steel in important parts. Due to the greater strength of this material, fabricated by welding, the 30-cu.yd. dipper weighs less, fully loaded, than did the old style 18-cu.yd. dipper and its load. Thus an increase of 67% of "pay dirt" was gained without increasing the gross weight. Comparable increases in capacity by the use of similar materials could be cited in other types of excavating and material handling machinery.

In stationary structures weight may seem to be of little importance. However, this is not always the case. Some members, especially beams that are highly stressed or confined to restricted space, present difficulties in design

which may be overcome by the use of high strength material. Saving of weight in the upper part of a structure may permit reductions in the supporting members. In cranes not only can substantial savings be made in the crane girders, but whatever reduction can be made in the supports is multiplied by the length of the runway.

A case in point is a design for new coal loading equipment which was to be placed on an existing pier. High tensile steel made it possible to keep the total weight within the permissible foundation load.

Of the 26 dams installed for flood control on the Mississippi River, 18 have gates and locks made of high tensile steel. Corrosion resistance was a primary consideration in the selection of the material, but weight reduction was more than an incidental advantage.

Metallurgical Development

These developments are the outcome of an increased determination to achieve savings by weight reduction. This in turn inspired new metallurgical developments in the basic metals required. Of course, numerous steels of high ultimate strength have long been available; one of these, the so-called silicon structural steel, has been used extensively in large

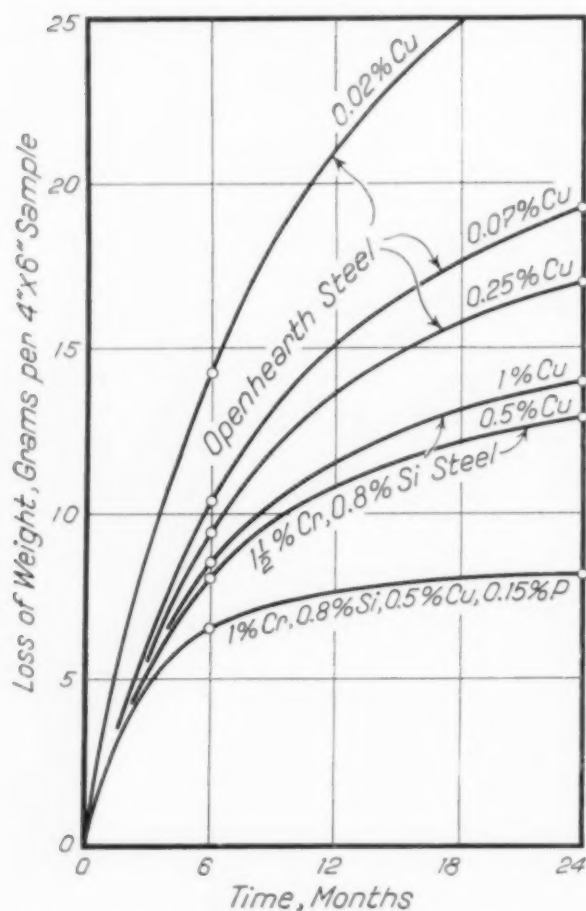


Welded Tank for Gasoline Transport "Drop Tested" for Toughness of Joints and Resistance to Puncture

bridges and buildings. Alloy steels which when heat treated developed high strength with adequate ductility have also long been standard materials for machines.

Why, then, were the older steels not adopted extensively for structural purposes?

The answer seems to be that in every one of them some important factor was missing. For instance, only in the last few years have we had low-priced steels having corrosion resistance combined with the other special physical characteristics. Neither



Exposure to Industrial Atmosphere Shows Influence of 0.25% Copper in Openhearth Steel Sheet, 0.5% Copper in Chromium-Silicon Steel, and Further Advantage of Phosphorus in Low Alloy Steel. (Analyses are typical rather than precise)

"high tensile steel" nor "high yield steel" is an adequately descriptive term. These new alloys are differentiated from the older steels not by any single property but by a combination of characteristics important to designers and fabricators.

The composition must be chosen so that the alloying elements will impart higher ultimate strength, and especially yield

point, in the as-rolled condition, without a marked reduction in ductility or in those characteristics known by the general term "toughness." Carbon and other elements which make steel susceptible to hardening by rapid cooling must be kept to the lowest practical limits, to adapt the steel for welding, forming and fabricating by all common processes without serious loss of ductility. In order that the initial cost will be little or no more than for conventional materials, the total cost of the alloying elements must be small, the losses from ingot to finished product must not be excessive, and the steel must work economically in the rolling operations. Since higher physical properties lead to the use of thinner sections, the desired high strength must be accompanied by increased corrosion resistance.

To illustrate the development of a high tensile steel having improved corrosion resistance, it may be of interest to sketch briefly the history of one which the writer has followed closely — the chromium-copper-silicon-phosphorus composition now known as "Cor-Ten." The first of its forerunners was a chromium-copper steel containing 1.0 to 2.0% chromium and about 0.4% copper, with carbon over 0.10%, and normal contents of manganese, silicon, sulphur and phosphorus. This steel was developed in this country about 1924; later it was commercially applied in several countries. Compared with plain carbon structural steel it had a moderate increase in strength, with only a slight loss in ductility. It made effective use of higher copper content and, under some conditions of exposure, gave substantially more resistance to corrosion than was obtained even from the conventional analysis containing slightly more than 0.20% copper (commonly known as "copper steel").

The next improvement was to increase the silicon up to 1.0%, resulting in a higher ratio of yield point to ultimate strength. Atmospheric exposure showed that corrosion resistance had been further improved and focused attention on this individual steel as the most promising of several hundred undergoing tests.

The effect of adding phosphorus to the chromium-copper-silicon steel was also investigated with surprising results. An analysis of exposure tests had shown the favorable action of phosphorus, and when it was added to the chromium-copper-silicon steel, the decrease in weight loss was about twice what would have been forecast from its effect in copper steel. This superior corrosion resistance was verified by tests of over two years' duration before the steel was offered for sale. Just how phosphorus produces such a pro-

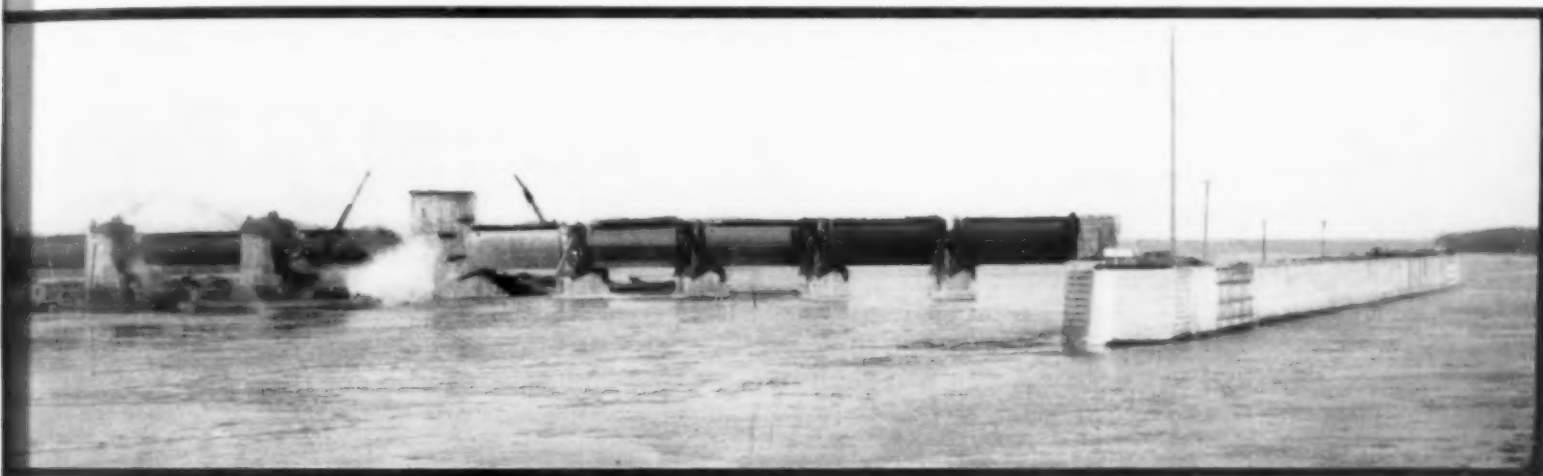
nounced effect in this particular range, in combination with the other elements, has not yet been fully determined.

Corrosion data from a two years' test in a severe industrial atmosphere are plotted in the diagram on page 40. Resistance to corrosion is directly attributable to the additional phosphorus, for all the other steels were normal or very low in this element. In steels of the general composition noted on the lowest line the phosphorus is roughly twice as effective as the same percentage would be in plain steel with sufficient copper to impart maximum corrosion resistance.

This chromium-copper-silicon-phosphorus composition has also demonstrated a marked

is deleterious has at last been generally discarded and this element has taken its proper position as a desirable addition.

It is, of course, recognized by metallurgists that the relative amounts of certain other elements are to be considered, as well as modern methods of steel manufacture. Thus, as has been stated by E. C. Bain and F. T. Llewellyn in the 1936 Symposium on Structural Application of Steel and Light Weight Alloys before the American Society of Civil Engineers, "A reduction of carbon content with a deliberate addition of phosphorus yields a steel in which strength is increased and ductility remains constant. . . At about 0.07% the strengthening effect of phosphorus is such as to necessitate



Dams Across Mississippi for Regulating Depth for Navigation Have Lift Gates. Here lightness and durability are desirable

degree of resistance to corrosion in salt spray, hot and cold fresh water, salt water and refined petroleum products. To those familiar with corrosion testing, it is scarcely necessary to say that such versatility is phenomenal.

Phosphorus has generally been condemned as a detrimental element when the content approached 0.10%, causing low ductility and brittleness in steel, particularly under vibratory conditions and shock. One who contested these ideas was J. S. Unger, who in 1918 showed that steels containing as much as 0.11% phosphorus could be bent, stamped and pressed cold, the same as similar steels with extremely low phosphorus. Cor-Ten, the first of the new class of low alloy, high tensile, corrosion resisting steels, derives not only additional corrosion resistance but also additional strength from a relatively high phosphorus content. Since its introduction and widespread successful use, the idea that phosphorus

a reduction of carbon content, but quantities as great as 0.15%, or even more, are useful under some conditions."

The generally accepted rule that the endurance limit of carbon and alloy steel is between 40 and 50% of the ultimate strength does not hold good in the Cr-Cu-Si-P steel. Normalized specimens having yield points from 52,000 to 54,000 psi. have endurance limits which agree closely with yield point. The ultimate strength of these specimens ranged between 76,000 and 83,000 psi., giving the exceptionally high endurance ratio of 66%. Hot-rolled specimens developed even higher endurance limits, as in these tests the values were again approximately equal to the yield point.

It may be said that if reasonable allowance is made for its new characteristics, almost any part that can be formed from plain carbon steel can be made also of these steels by slight adjustments, such as providing increased radii

for bends and more allowance for spring-back in forming operations.

Adaptability for welding is a particularly important characteristic, because welded construction permits further reduction in weight by elimination of bulky connections. A report of the American Welding Society recently referred to several of these new compositions as "fool-proof welding steels," thus expressing the fact that they retain adequate ductility in and around the weld almost irrespective of the method by which it is made. This term should not be taken to mean that the precautions necessary to make good welds in ordinary steel can be disregarded!

Some have attempted to match the composition of the base metal and the electrodes used in metallic arc welding. This is seldom necessary because reinforced welds made with coated mild steel electrodes usually provide sufficient strength and excellent ductility, and have ample section to prevent undue loss of strength from corrosion at the weld.

Questions have sometimes been raised regarding the ability of extensive welded seams to withstand severe impacts in structures such as tanks where elongation would reduce only the thickness of the part and not its width. Tests have been conducted to determine the resistance of carbon steel and high tensile steels welded by the metallic arc process when subjected to violent explosions. Details of the tests cannot be given within the scope of this paper, but it can be said that the results were eminently satisfactory.

An authority on metallurgy has expressed the opinion that the time may come when high tensile steel, now regarded as a special material, may supersede carbon steel as the ordinary structural steel. It is easy to accept this view if the new steels are regarded as ordinary steel to which superior properties have been imparted by minor changes in composition. They should hardly be classed as alloy steels. They are produced by the openhearth process in tonnage mills; they are formed and fabricated in the same manner as plain steel. They are sold at prices which, per unit of strength, are comparable to the prices of ordinary steel. Where designs are suited for these new materials, their use often involves no additional cost or produces economies that yield large returns on the relatively small extra expenditure. In such cases it seems evident that the market for them will continue to expand rapidly.

Materials for Aircraft

By H. J. Gough

Abstracts from lectures before Royal Aeronautical Society
(*The Engineer*, June 3, p. 626)

FOR MANY YEARS wood, covered by fabric, formed the principal material of construction and in many ways it was and still is a satisfactory material. Wood is easily worked and the strength characteristics of selected timber are generally very reliable; it is not subject to corrosion and in temperate climates shrinkage may not be an important factor. In today's planes (monocoque structures) it has the drawback that its shear modulus is too low for economical use as a stressed covering.

The first all-metal planes produced in England were constructed in 1919, both in steel and aluminum. The design of the purely monocoque structure, utilized then, has really undergone very little essential change during the intervening years.

The relative merits of the available structural materials cannot be determined without considering the form of the ship. In a biplane one might prefer all-steel construction and it is doubtful whether there would be any advantage gained in weight or ease of fabrication by the use of light alloy; in fact, any such advantage would largely depend on the experience and production facilities of the constructor concerned. Careful design has made possible the use of thin high tensile steel strip in which very high stresses may be developed, while steel spars and other structural members lend themselves very readily to methods of mass production.

In comparing beams of similar cross-sections, having the same strength in bending, but made of two different materials, the ratio of the stiffnesses is $(E_2/E_1)(f_1/f_2)^{4/3}$, while that of the weights is $(w_2/w_1)(f_1/f_2)^{2/3}$, where E_1 and E_2 , f_1 and f_2 , w_1 and w_2 are the elasticities, strengths, and densities, respectively, of the two materials. Now, very roughly, E , f , and w are in the same ratio for all structural materials and hence, in similar forms of structure, the lighter materials give a lighter and stiffer structure.

Thus it would have been a retrograde step to replace solid wooden spars by solid metal ones and the advantage of metal could only be realized by the use of thin-walled construction. But such construction at once introduced the problem of secondary failure by instability under compression and shear at stresses much lower than the maximum the material itself can safely withstand. This instability in shear can be reduced by local stiffening; curvature of the plate is appropriate when the stress is compressive. (Continued on page 76)

By Robert G. N. Evans
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Coefficient of friction

is a minor factor in

bearing design

WE HAVE BEEN ASKED a great many times for data on the coefficient of friction of the various bronzes used for bearings, so the alloy chosen by the engineer might be the one with the lowest friction. We have not issued such a table because there are so many variables always present in the application, to a lesser or greater degree, which directly affect the results obtained from an experiment on the coefficient of friction made in laboratory equipment. An explanation of this situation is needed.

In the first place, what is friction?

Robert H. Thurston describes it on page 14 of his book entitled "Friction and Lost Work" as follows: "Friction is that familiar resisting force which always acts to prevent or to retard the relative motion of one particle or body in forced contact with another."

What kinds of friction are there?

Again, to quote from Thurston: "It is of three kinds: Sliding and rolling friction, acting between solids, and fluid friction, which acts when the particles of liquids or of gases move in contact with each other or with other bodies." While this explanation of Dr. Thurston's may not describe friction to the satisfaction of all

technicians, it will suffice for our purpose.

In sleeve type bearings, we are generally concerned with sliding and fluid friction. Sliding friction is due to the turn of the shaft in the stationary bearing, or vice versa; fluid friction exists in the lubricant, which is acted upon by the opposing forces of shaft and bearing in relative motion.

Immediately, therefore, we arrive at one of the variables directly influencing any comparison of sliding friction, namely the *finish* of the bearing surfaces on shaft and journal. It is obvious that two lubricated surfaces, to slide one over

the other without effort, must be perfectly smooth and the lubricant must also have zero viscosity. Mirror-like finishes in bearings (produced in various ways), and lapped shafts are ordinarily spoken of as being smooth and true surfaces, but if we could examine these surfaces under high enough magnification, we would find them covered with minute tentacles which would entwine with one another if the surfaces are rubbed together dry, retarding free movement between them; hence, friction; subsequently, generated heat.

For instance, we are all given to regard the surfaces on Johansson gage blocks as being "the perfect finish," but we must remember that when rubbing or wringing two of these blocks together, no air is permitted to remain between them, being true surfaces, and they will stick together. This is adhesion, and perfect surfaces have entirely stopped movement.

In the case of these gage blocks, the two surfaces are flat. Were they curvatures, one concave and the other convex with the same radii, the results would be comparable. However, in sleeve bearings, due to the fact that allowance must be made between shaft and bearing for running clearances, different diam-

Properties of Some Bearing Bronzes

Bunting Alloy and No.		Chemical Analysis									Sn-Cu Ratio
		Cu*	Sn*	Pb*	Zn*	Fe†	Sb†	Ni	P†	Others†	
161	(High lead)	63	2	35	—	0.20	0.20	0.25	0.03	0.10	0.032
122		72	3	25	—	0.20	0.20	0.25	0.03	0.10	0.042
178		68	4	28	—	0.20	0.20	0.25	0.03	0.10	0.059
158		70	5	25	—	0.20	0.20	0.25	0.03	0.10	0.071
125		75	4.5	20.5	1	0.20	0.20	—	0.05	0.35	0.060
124	(Stock)	85	5	9	1	0.20	0.20	—	0.10	0.35	0.059
135		77	8	15	1	0.20	0.20	—	0.05	0.50	0.103
162		70	9	21	—	0.20	0.20	0.25	0.03	0.10	0.127
72		83	7	7	3	0.20	0.20	—	0.07	0.50	0.084
27		80	10	10	0.75	0.20	0.20	—	0.10	0.50	0.125
146	** (Stock bars)	83.5	10	5	1.50	0.20	0.20	—	0.10	0.25	0.120
72		83	7	7	3	0.20	0.20	—	0.07	0.50	0.084
96		87.5	10	2.5	1	0.20	0.20	—	0.10	0.50	0.114
51		86.5	10	1.5	2	0.20	0.20	—	0.10	0.50	0.116
147		88	8	1	3	0.20	0.20	—	0.10	0.25	0.091
98	(Leaded gun metal)	88	10	—	2	0.06	0.20	—	0.10	0.25	0.113
156		89	11	—	—	—	—	—	0.20	0.50	0.124
164		86.5	11	1.25	—	0.30	0.20	1.00	0.25	0.10	0.133
143		85	14	1	0.25	0.20	0.20	—	0.10	0.25	0.165
116		6	86†	†0.35	—	0.08	7	0.10†	0.08	—	—
170	(Lead bronze)	0.25	10	75	—	0.08	15	0.20†	0.08	—	—

Alloy No.	Room Temperature Properties								Specifications		
	Brinell	Rockwell	Order of Non-Scoring	Tensile Strength	Yield Strength	Elongation	Compressive Limit	Relative Resistance to Deformation	S.A.E.	G.M.C.	Others
161	28	—	1	12,000	5,000	5	8,000	12	—	—	Cadillac 34 Westinghouse, high lead
122	35	—	2	15,000	7,000	5	10,000	11	—	—	
178	36	—	3	18,000	8,000	5	12,000	10	—	—	
158	38	—	4	20,000	10,000	8	13,000	9	—	4074-M	
125	40	—	5	22,000	11,000	12	14,000	8	—	—	
124	50	—	6	28,000	14,000	15	17,000	7	66	4054-M	B 31-21 (A.S.T.M.)
135	52	—	7	30,000	14,000	15	18,000	6	67	—	
162	55	—	8	30,000	15,000	15	20,000	5	—	4075-M	
72	58	59	9	34,000	16,000	20	20,000	5	660	4182-M	
27	60	63	10	35,000	17,000	20	21,000	4	64	4050-M	
146	60	63	11	35,000	17,000	15	21,000	4	—	4072-M	Ford Z metal Gun metal Gear bronze Synchronesh rings, Cadillac 32 High tin, hard bronze
72	65	71	9A	37,000	17,500	8	22,000	3	660	4182-M	
96	65	71	12	40,000	18,000	20	22,000	3	63	4216-M	
51	65	71	13	40,000	18,000	20	22,000	3	—	—	
147	65	71	14	40,000	17,000	15	22,000	3	—	4046-M	
98	67	73	15	40,000	18,000	20	23,000	2	62	—	Synchronesh rings, Cadillac 32 High tin, hard bronze
156	67	73	16	40,000	18,000	20	23,000	2	65	—	
164	75	77.5	17	40,000	18,000	12	23,000	2	—	4071-M	
143	85	85.5	18	40,000	15,000	10	24,000	1	—	—	
116	—	—	—	—	—	—	—	—	11	4027-M	
170	—	—	—	—	—	—	—	—	—	—	

* Mean figures. Tolerances in practice are generally $\pm 0.5\%$ on contents up to 5%, $\pm 1.0\%$ on 5 to 12%, $\pm 2\%$ on 13% and more.

** Bars or bearings made in mechanized molds

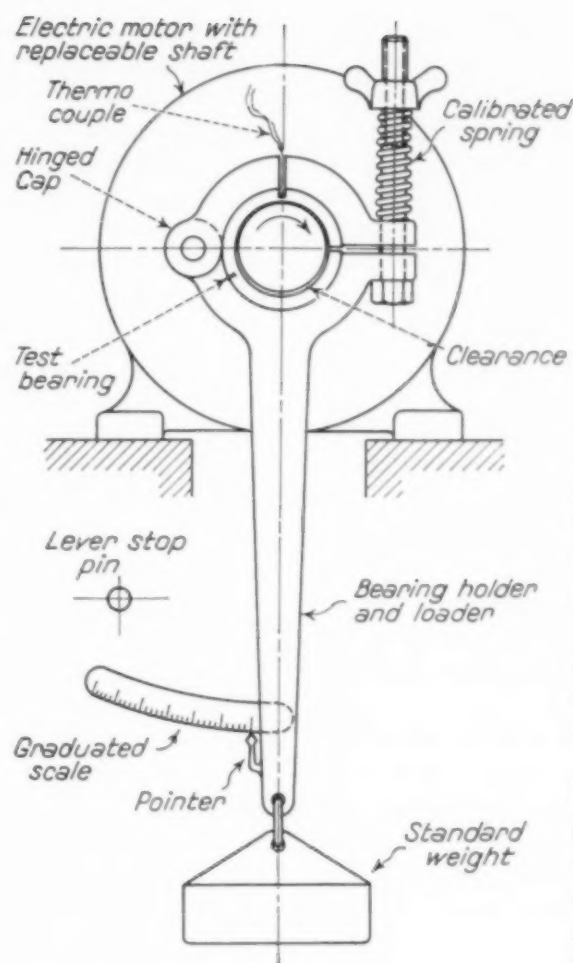
† Maximum or maximum total

‡ Minimum

eters are produced, and line or point contact between shaft and bearing is the result, and adhesion of this nature is not possible. But the finish on the shaft and bearing is of the greatest influence in producing friction, or drag, when there is absolutely zero lubrication.

When a lubricant is injected between mating surfaces, finish is again an important factor, because two rough surfaces, moving in opposite directions, plow through the oil and bring fluid friction into the picture. Rough surfaces have an additional harmful effect of rupturing the oil film, which, being broken between the high points on shaft and bearing, will allow instantaneous metal-to-metal contact. This accounts for scored bearings, even when a good volume of lubricant is present and oil circulation is constant. A groove in the high pressure area produces the same result. Even another harmful action appears, especially under shock loading. It would almost seem that single molecules of lubricant (which are probably very complex and large associations of dozens of atoms) are caught between rapidly moving metal protrusions and broken apart. This results in a chemical change by purely mechanical means, and a gradual deterioration of the properties of the oily film.

In view, therefore, of the numberless variations in the above factors of surface finish, fit and lubrication, it is plain that any figures for coefficient of friction would be of small use in machine design. In fact, the most precise laboratory experimentation is necessary to secure results that really compare one alloy against another. Regardless of the test procedure, the microstructure, hardness and other physical properties of the mating surfaces must be under strict control, and the finish on test specimens must be absolutely the same in check tests, else



Sketch of Machine for Finding Relative Resistance to Scoring of Bearing Bronzes

the results will not be comparable.

In practice bronzes are better evaluated by their "bearing characteristics" rather than by their chemical analysis and their coefficient of friction. While there is a rough relationship between the three, the influence of chemical analysis on bearing characteristics is quite indirect, as will be mentioned later. But first a definition of "bearing characteristics" is in order.

The principal bearing characteristics are classed as structure and resistance to scoring.

The structure of the bearing should have sufficient compressive strength to carry the imposed load—shock or steady. It must not "pound out" or conform exactly to the shaft radius. In this respect it should be remembered that the ability of a bronze to

carry load with a given minimum deformation increases as the wall thickness decreases (other factors remaining constant), this being responsible for the fact that thin-walled bearings offer distinct advantages. Bronzes of various compositions may be compared in this respect by comparing their compressive strengths. Since the bronzes are essentially alloys of copper and tin, the ratio between these two elements in the analysis is a rough measure of the compressive strength (and the structure, in the above sense) for the tin-copper ratio governs the amount of delta or hard constituent in the microstructure, as well as the inverse amount of alpha or soft constituent. As the tin-copper ratio goes down, the amount of soft constituent increases, the compressive limit decreases, and the non-scoring bearing characteristics go up.

Resistance to scoring must be as high as possible. In general, this is contradictory to the above-mentioned requirement, for the softer bronzes are the best as far as non-scoring characteristics are concerned. Consequently

we ordinarily strike a balance between the desire for a strong structure and a low resistance to scoring. Such a compromise is achieved in our alloy No. 72 (specification No. 660 of the Society of Automotive Engineers or No. 4182-M of General Motors Corp.), a proven bearing material for general purposes. Referring to the list of alloys on page 44, and using alloy No. 72 as a comparison standard, where the bearing characteristics go down the coefficient of friction will go up, and vice versa.

Using that table, an engineer might decide to use No. 161 alloy because it had a low coefficient of friction; yet by improperly finishing the shaft and bearing, or improperly locating the oil groove, such a bearing would produce a greater drag or power loss than would one made of a much harder alloy, properly finished and with oil grooves correctly located at the point of closest approach to the high pressure area of the bearing.

There are certain exceptions to the above general procedure. For instance, when high speeds, light loads, and close tolerances are required, S.A.E. 63 alloy would probably be used in order to get an extremely smooth finish. But if the magnitude of the load made it neces-

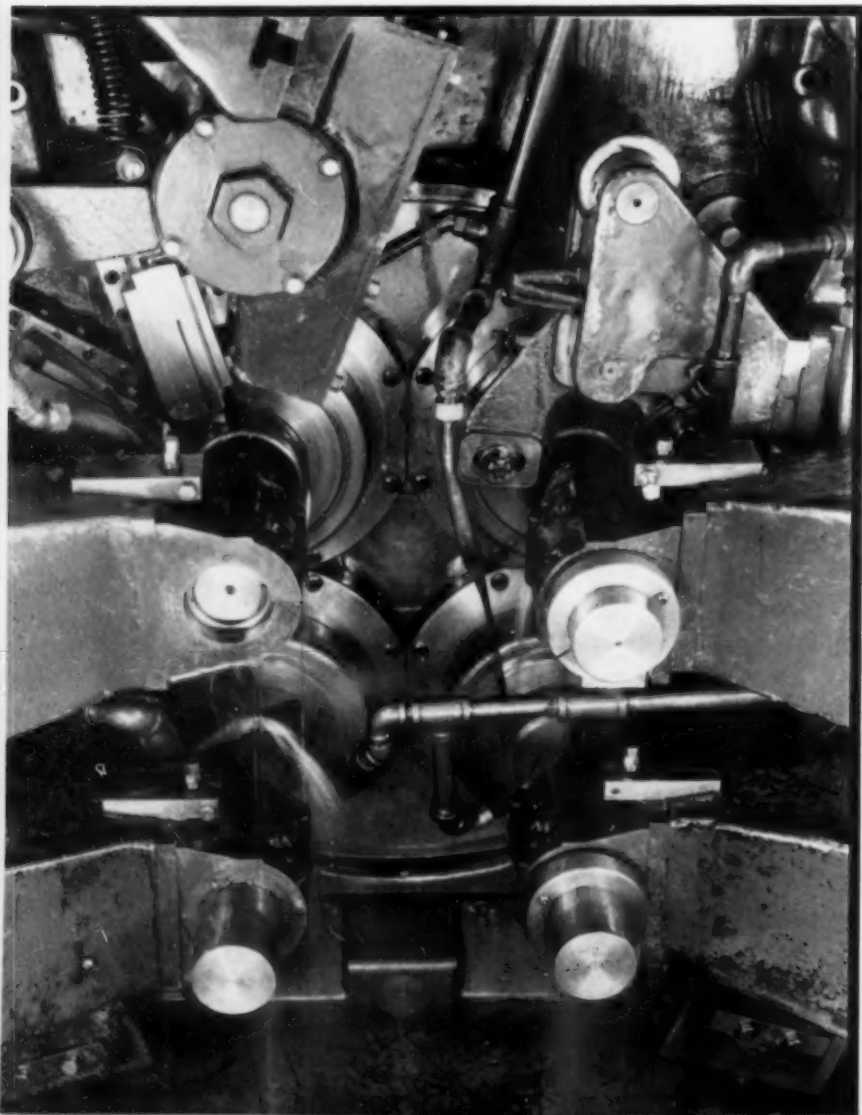
sary for us to choose an alloy to resist deformation, we would probably take Group 3 in the column headed "Resistance to Deformation" in the table, and the No. 72 alloy produced in mechanized mold would be favored, since it possesses the greatest amount of non-scoring characteristics.

This matter of non-scoring characteristics is important enough to show how the alloys are rated. A special machine, illustrated in the sketch on page 45, is used, consisting of a small electric motor so arranged that its shaft is easily replaceable. This shaft carries an arm which acts as a bearing holder and a loading device. The test bearing in each experiment was diamond bored and placed carefully in the bearing holder. Testing was done without lubrication and the clearance was the same in each case as well as was the calibration of the load in the spring. The suspended weight was constant. The electrical input was noted on a watt meter without load so that the check could be made, considering the current demand with the load and the drag produced by friction. A stop watch was used to measure the time between starting and freezing. A thermocouple and potentiometer gave us the temperature of the bearing in the high pressure area. New shafts were used with each bearing specimen that was tested in the machine.

In conclusion, it may again be stated that coefficient of friction can be determined for a multitude of shaft and bearing combinations, but this information would lead to wrong applications of bearings unless a number of other variables are considered. In selecting an alloy for a definite application, *bearing characteristics*, not analysis nor coefficient of friction, are determining factors. The ability of the bearing structure to support the imposed load and the non-scoring characteristics of the alloy are the two factors of most importance in selecting the material. The bearing itself may then be designed for a wall thickness which allows an alloy with the greatest amount of non-scoring characteristics to be used, with proper proportions of length to diameter, and grooved for adequate distribution of lubricant.

Specifying of physicals on blueprints, together with analyses, should guarantee correct structures. Almost any foundry can produce castings within the chemical specifications set up, but if control of foundry procedure were lacking, the correct physicals could not be consistently produced in the finished bearing.

If Civilization Rides on Wheels, Every Wheel Must Have Its Bearing; the Better the Bearing the Smoother the Ride



Plain chromium irons

—their toughness & weldability

By Vsevolod N. Krivobok
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and the Alloys of Iron and Chromium, Vol. II, to be published by the Engineering Foundation. Deliberately, therefore, they will be brought in only insofar as is required to indicate how they may be altered by methods of construction or conditions of continuous service. If such properties are affected adversely, it is intended to discuss methods to prevent or minimize it.

A concise summary of the expected physical properties of the plain chromium-iron alloys is found in the first table (page 48). Corresponding to commercial practice, they are grouped under (a) 16 to 20% Cr and (b) 23 to 30% Cr. In com-

mercial parlance all these alloys are called "steels." Those of the 16 to 20% group which harden considerably on quenching can be properly so called, but the 23 to 30% chromium-irons, insensitive to heat treatment and of ferritic structure at both high and low temperatures, are better called "irons."

Heat Treatment of the 18% Cr-Fe

This modification in properties by means of heat treatment is a function of chemical analysis—important enough knowledge to be particularly mentioned. As an example a series of alloys with their properties after certain heat treatments may be cited. The figures given in the second table, page 49, although typical, may vary with the prior history of the metal.

For otherwise identical analysis (within commercial limits and on commercially made heats) the two elements carbon and chromium have, generally speaking, opposite effects. With increasing chromium content the susceptibility to hardening is decreased. With increasing carbon content the same susceptibility to hardening

THE SUBJECT "Characteristics and Fabrication of Stainless Steels Containing More Than 14% Chromium" assigned for a paper for the Western Metal Congress is so extensive that subdivision is needed, even in such a specialized discussion as is contemplated. Therefore the matter will be presented in three sections:

1. Chromium-iron alloys with no additions other than carbon, or with additions of other elements in such amounts that the microstructure (predominantly ferrite) is not altered.

2. Chromium-nickel-iron and chromium-manganese-iron alloys pseudo-austenitic in nature; also the same alloys with further additions, the purpose of which is to minimize or eliminate the dangers which may ensue should pseudo-austenitic alloy revert, in the process of fabrication or service, to its stable condition.

3. Thoughts and facts pertaining to "permanency" as expected of stainless alloys.

Mechanical properties of all these alloys have been discussed in a great number of publications and the facts assembled in two readily accessible books, *The Book of Stainless Steels*, published by the American Society for Metals,

Portions of a paper read at the Western Metal Congress

Characteristics of Straight Chromium-Iron Alloys

	16 TO 20% Cr (0.12 C MAX.)		23 TO 30% Cr (0.30 C MAX.)	
Microstructure	Ferrite with a little pearlite		Ferrite	
Effect of heat treatment	Somewhat modified		Not modified	
Effect of cold work	Modified		Modified*	
Room temperature properties	ANNEALED	COLD WORKED	ANNEALED	COLD WORKED
Tensile strength, psi.	75,000 to 90,000	90,000 to 190,000	75,000 to 95,000	85,000 to 175,000
Yield point, psi.	40,000 to 55,000	65,000 to 130,000	45,000 to 60,000	55,000 to 135,000
Elongation in 2 in., %	30 to 20	20 to 2	30 to 20	25 to 2
Reduction of area, %	55 to 40	40 to 20	60 to 50	50 to 20
Izod impact, ft.-lb.	75 to 5	30 to 2	Very low	Very low
Brinell hardness	140 to 180	175 to 275	140 to 180	150 to 250
Strength when hot, psi.				
1000° F.	47,500 to 54,000		49,000 to 52,000	
1100° F.	37,000 to 41,000		20,000 to 34,000	
1300° F.	15,000 to 23,000		10,000 to 15,000	
1500° F.	8,000 to 12,000		6,000 to 7,500	
Creep strength (1% in 10,000 hr.)				
1000° F.	5,500 to 8,500		6,000 to 7,000	
1100° F.	2,300 to 5,000		2,700 to 3,300	
1200° F.	1,300 to 2,100		1,600 to 1,800	
1300° F.	1,000 to 1,400		500 to 800	

*Age hardening and similar treatments are excluded

is increased, especially within the lower range of chromium, being much less marked when chromium is at the higher limit of the stated range. The information on susceptibility of these alloys to hardening by cooling in air, which the table contains, is of much interest to the constructor, especially the welding engineer — and the discussion will shortly revert to it.

Impact characteristics of this class of material are sometimes of importance. The obtainable values may be as high as 100 ft.-lb. but depend very much on processing, especially in higher alloys. Further, they are greatly influenced by the temperature of testing, and in common with many engineering materials, lose toughness at temperatures near freezing, while gaining much in toughness even at the temperature of boiling water. These facts are shown in the curves on page 50. However neither the ductility nor the strength in tension is adversely affected by refrigeration to -70°C .

Fatigue strength of these alloys follows pretty close the generally accepted rule, namely that in absence of corrosive conditions the fatigue strength is approximately half the tensile strength. Information pertaining to fatigue is, by the way, a very fertile field for studies — especially in even mildly corrosive media.

Since these alloys are ordinarily used at elevated temperatures their strength when hot is of utmost importance. The general summary

of such properties, based on "short time" tests and on available creep tests for long time at constant load, is given in the table above. It must be thoroughly understood that many variables influence the creep strength, variables such as microstructural condition of the metal subjected to test, interruption in service conditions, the nature of the atmosphere and the nature of the applied stresses. This, of course, applies to other metals and alloys as well, and necessitates a most careful examination of all the attending circumstances.

High Chromium Irons

A large and very important class is the one which we group together for convenience as alloys containing from 23 to 30% Cr. These alloys are well adapted for services at high temperatures, especially where intermittent cooling and heating is encountered. Mechanical properties of these alloys at room temperature are not affected, except to a slight degree, by heat treatment, as is shown by the following data for one analyzing 28% Cr, 0.07% C, 0.60% Mn and 0.30% Ni:

CONDITION	TENSILE	YIELD	ELONGATION
Annealed	59,800	77,700	30.0
1500° F., 3 hr., air cooled	56,900	88,700	30.0
1700° F., 3 hr., air cooled	59,700	81,500	—
1700° F., 3 hr., water quenched	62,000	82,500	28.0

It can also be shown that variations in carbon and chromium contents within the limits for this class of material have no effect on the *susceptibility* to heat treatment. The following limitation should, however, be mentioned: Upon heating to above 2000° F. grain growth occurs, resulting in diminished strength and loss of ductility as measured by elongation in the tension test, which would drop from 28 to 30% to less than 5%. This loss of ductility upon reheating to high temperatures is an important circumstance in the fabrication and use of these alloys to which we will refer later.

Effect of Heat Treatment on 16 to 20% Cr-Fe Alloys

ANALYSIS			CONDITION*	MECHANICAL PROPERTIES				
C	Cr	Ni		BRINELL	YIELD POINT	TENSILE STRENGTH	ELONGATION	REDUCTION OF AREA
0.06	15.98	0.18	Normalized	217	88,000	128,700	12	23
			Annealed	137	37,600	70,700	30	66
0.11	15.70	0.18	Normalized	267	120,000	156,600	9	23
			Annealed	156	42,800	78,800	29	66
0.10	16.64	0.36	Normalized			103,000	3	
			Annealed			68,600	30	
0.09	17.48	0.40	Normalized	187	58,400	89,700	6	
			Annealed	140	47,100	68,400	30	56
0.13	17.44	0.25	Normalized	217	85,800	115,200	3	
			Annealed	143	45,000	76,300	28	57
0.08	20.96	0.47	Normalized	156	52,300	78,300	18	19
			Annealed	159	50,300	72,700	31	67
0.13	20.52	0.41	Normalized	187				
			Annealed	163	53,900	82,800	25	58

*Normalized: One hour at 1830° F., cooled in air.
Annealed: Two hours at 1550° F., cooled in furnace.

Alloys of these compositions are deprived of toughness—their impact strength is very low. While the grain can be refined by deliberate additions of nitrogen, the problem of impact brittleness has not yet been solved. It should be pointed out, however, that the ductility in the tension test is not lost even at low temperatures. As shown in the first table the mechanical strength at high temperatures is comparable to that of the 16 to 20% Cr-Fe alloys, except at high temperatures (1500° F. or up) where it apparently drops off.

Welding the Chromium-Iron Alloys

It was with deliberation that certain characteristics of straight chromium alloys were stressed, namely, certain air-hardenability of the 16 to 18% chromium alloys and grain growth

at high temperatures of 23 to 30% chromium irons. With the rapidly growing importance of stainless steels as an engineering material it is quite obvious that in many installations their use is dependent upon welding as a method of construction. Alterations in microstructure and physical and chemical properties taking place during the welding operations, and the new characteristics imparted to the high chromium alloys will be now discussed.

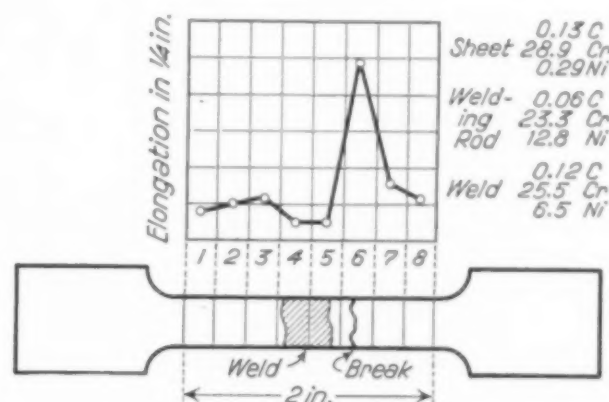
As it is generally carried out, welding implies local heating up to very high temperature followed by cooling in air. This corre-

sponds to a treatment conducive to hardening in some of the alloys and grain growth in the others. Annealing of the finished article is frequently impractical and, under some circumstances, impossible. Furthermore, annealing of the 30% chromium irons does not refine the grain size.

To avoid producing local hardened regions from $\frac{1}{32}$ to $\frac{1}{16}$ in. thick adjacent to the weld, with the attending relative brittleness, several means may be employed, each rendering the stainless alloys under discussion thor-

oughly acceptable as materials for welding.

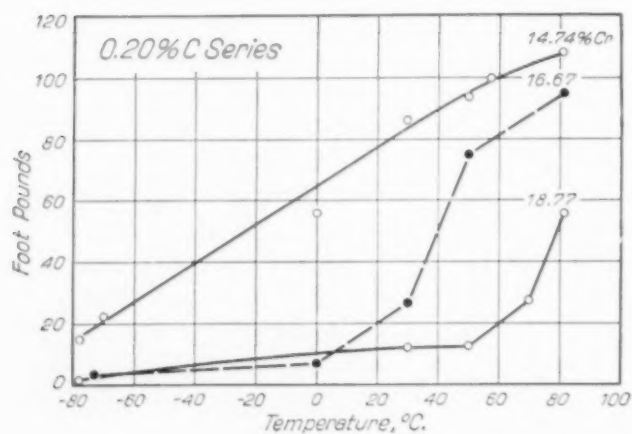
One such method is to use high chromium, high nickel welding rod of standard analysis. With this technique welded structures made of



Sketch Showing Distribution of Elongation in Welded Test Piece in 16 to 20% Chromium-Iron Sheet

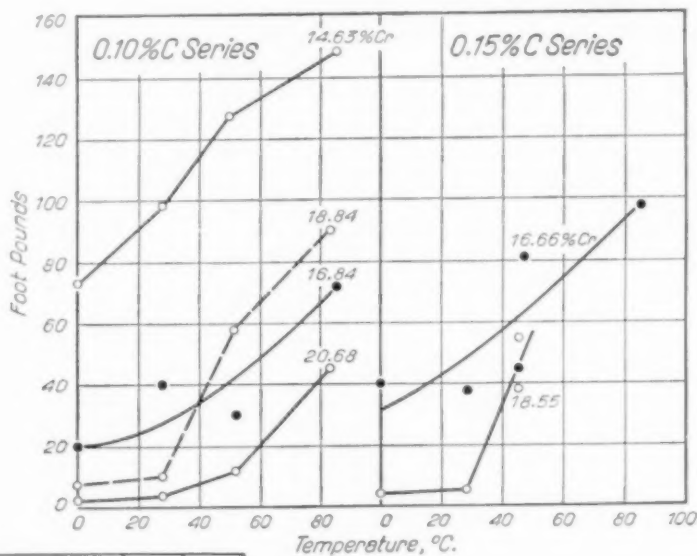
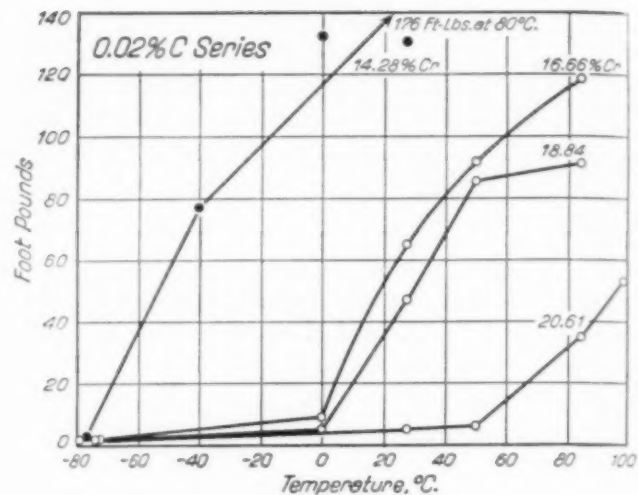
alloy plates containing from 16 to 20% chromium are secured with needed ductility, the degree of which is of course controlled by the analysis and the gage of welded material, the design, and other engineering factors. Thus, it is no longer necessary to have welded samples which "break after rather a slight bend through the affected zone next to the weld proper," as was repeatedly stated verbally and in print. Neither is it necessary to resort to annealing, in order to restore the ductility of the "affected area," as was formerly recommended, unless annealing is for the purpose of stress relieving. The strength of the welded joint is greater than the strength of the parent metal. This is shown in the sketch at the foot of the preceding page, in which is also recorded the distribution of elongation throughout the welded assembly.

Ductility of welded alloys with 23 to 30% chromium is benefited to a smaller degree and is more dependent



upon the gage. The illustration on page 51 will show to the interested reader that in fairly thin gages the available ductility is high. This will be somewhat diminished in heavy sections, if it is judged by mechanical deformation such as bending; however, in most engineering construction the ductility of even heavy sections will be found adequate.

Corrosion resistance of alloys with 23 to 30% chromium is so excellent that their instal-



Izod Impact of Chromium-Iron Alloys Is Generally Low at Arctic Temperatures But Improves Greatly at Temperate (and Likewise at Elevated) Temperatures.

lation is naturally suggested whenever many corrosive media must be handled. The use of welding rod of dissimilar material may cause an accelerated rate of attack (in the presence of the electrolyte) and in some installations it may be advisable to foresee and counteract this possibility. A "compound" weld may be utilized, such as a layer of the plain chromium alloy on that side which will be in contact with electrolyte, over other weld metal high in nickel, as was suggested before as being proper to secure strength and ductility in the joint.

Interesting observations can be made regarding the use of chromium-nickel-iron rod in conjunction with straight chromium-iron base metal. Nickel contained in the weld rapidly diffuses outward, toward the base metal, so that the bead laid with 25% chromium, 12% nickel rod will contain only approximately 6% nickel after welding is completed, while the chromium remains practically the same, allowing for a small loss suffered during welding. No appreciable increase in the hardness in the areas adja-

cent to the weld are noted after welding, despite the diffusion of nickel. Thus, measurements made across the welded sample of 28% chromium iron showed hardness to be between B-84 and B-90 Rockwell.

Modifications of the Chromium Irons

The moderate hardenability which alloys with 16 to 20% chromium exhibit upon quenching or air cooling is decreased by additions of titanium, columbium or aluminum. The specific effect of 0.20% aluminum in an alloy containing 0.11% carbon, 16.50% chromium and 0.30% nickel is as follows:

	No ALUMINUM	0.20% ALUMINUM
Air cooled from 1450° F.		
Tensile strength, psi.	67,000	67,800
Elongation in 2 in., %	28	27
Slowly cooled from 1800° F.		
Tensile strength	68,000	65,500
Elongation	26	29
Air cooled from 1800° F.		
Tensile strength	106,000	86,500
Elongation	3	16

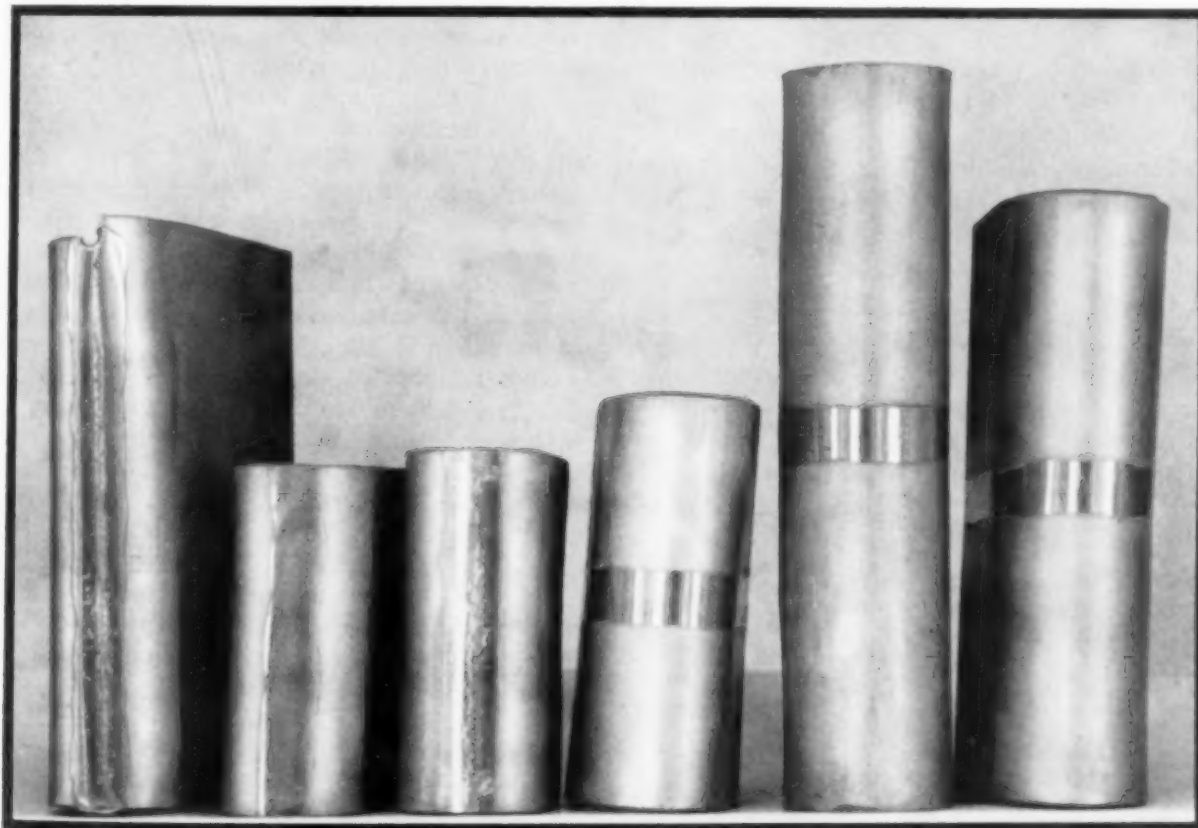
Consequently, in applications or in constructions in which the corrosive characteristics of the metal prove adequate, and in which the

ductility of the metal and of the welded parts is essential, the consideration of this alloy with aluminum is suggested. The recommendation for the welding rod material would again be high chromium, high nickel alloy. (It may be mentioned, while we are on this subject, that with this method of welding, air hardenable alloys such as 12% chromium steel can be made to possess excellent weld ductility.)

Commercially available chromium alloys under discussion, whose compositions are modified by the additions of some other elements for the purpose of bettering some particular property, are not very numerous. Doubtless this is due, at least in part, to the satisfactory performance of straight chromium alloys under the conditions of service for which they could be recommended. This should not, of course, be interpreted as meaning that the possibilities for further improvement are exhausted. Quite the contrary.

Nickel and tungsten, also copper, silicon and molybdenum, are found as additional elements in commercial alloys containing from 14 to 18% chromium. Additions of 1.0 to 2.0% of nickel to alloys containing from 16 to 18% chromium has been advocated from time to time,

Welds in Fairly Thin Plates of 23 to 30% Chromium Iron Will Withstand Considerable Bending if Made With 18-8 Welding Rod



especially by English firms. Such additions result in considerably increased strength and elastic ratio with accompanying lowered elongation. Although in the majority of cases the strength of material is not the only consideration, alloys of this type enjoy a limited field of application. This is equally true of alloys with 18% chromium and as much as 5% nickel which, because of their strength and high elastic properties, are suitable for certain applications. Some recent technical publications advocate the addition of 1% silicon and 1% copper for similar purpose.

The purpose of adding tungsten (usually about 3%) is to increase strength at elevated temperatures. From Germany come recommendations to add nickel for the same purpose, while in Russia the metallurgists recommend higher carbon (0.60 to 0.70%) and 1 to 3% of molybdenum, cobalt and tungsten, used mostly in combination. It is stated that the latter steels are apt to lose their ductility under conditions of intermittent heating and cooling. Copper, silicon, molybdenum and aluminum are added in various amounts to secure either increased resistance to some particular corrosive environment, or—as in the case of aluminum—to provide us with an alloy of exceptionally good resistance to oxidation at high temperatures.

High Aluminum Alloys

According to a very recent foreign publication three analyses of chromium-aluminum-iron alloys are employed for continuous use at high temperatures: (a) 10 to 15 Cr, 5 Al, 0.10 C for temperatures in the range 1650 to 1750° F., (b) 20 to 30 Cr, 5 Al, 0.15 max. C for temperatures of 2100 to 2200° F., and (c) 37.5 Cr, 7.5 Al, 0.15 max. C for continuous use at temperatures up to 2375° F. The first mentioned alloy has been made and used commercially in our country, and is stated to be especially resistant to sulphur bearing gases.

Our unending efforts toward the ultimate in engineering efficiency create greater and greater demands for alloys of higher chemical and mechanical stability. A very large number of complex alloys is being continually proposed to meet the demand. To enumerate them in detail would not serve any useful purpose; such information is found in the book "Engineering Alloys" by Woldman and Dornblatt. Furthermore, the record and serviceability of most of these alloys should first be established.

Automatic Bright Plating of Nickel and Cadmium

By J. Kronsbein

Abstract of paper for Electrodepositors' Technical Society
(*The Metal Industry*, May 13, 1938, p. 509)

WITHIN ABOUT A YEAR bright nickel plating has reached a point where it is fully automatic. Equipment at Standard Motor Works at Coventry, England, consists of a series of tanks in line, occupying a floor space of 8x48 ft., with capacity of 3,500,000 die-cast door handles per year of 2000 hr., and another 8x60, which can plate 40 radiator grills per hr. Line-up of tanks for brass and steel is as follows:

(1) Electrochemical cleaning in hot caustic alkali. (2) Cold water rinsing. (3) Auxiliary cold cyanide cleaning. (4) Cold water rinsing. (5) Weak acid dipping. (6) Cold water rinsing. (7) Bright nickel plating by the Hinrichsen process. (8) Preliminary cold water rinsing. (9) Cold water rinsing. (10) Chromium plating. (11) Preliminary cold water rinsing. (12) Running hot water rinsing. (13) Air drying at room temperature.

For processing zinc die castings a copper vat is included in the line because zinc dissolves in the acid nickel plating solution, roughening the article and rapidly contaminating the solution for bright nickel plating. In the line for light hardware the nickel plating vat is only 8 ft. long, the chromium vat 5 ft., and the conveyor chain speed is of the order of 6 to 8 in. per min.

Such short plating times are due to the high current density—45 to 50 amperes per sq.ft. In another plant 80 amperes per sq.ft. is used without pitting, impairing brilliance, or necessitating critical control. This means that the usual specification plate of 0.0006-in. thickness on brass can be applied in 12 to 15 min., so that the nickel plating tank in the automatic line may be considerably shorter than would otherwise be necessary with a plating solution of slow action.

Transfer mechanism has been much simplified so that one drive operates all transfers simultaneously, lifting the correct carrier bars off the conveyor chain, up, across the partition, and down to another link on the conveyor chain in the forward tank. These movements, in relation to the chain, are rapid; in fact, the work is transferred from one tank into the next in about 20 sec. Rapid transfer of work from vat to vat becomes of great importance in bright nickel plating because the work should not be allowed to dry between nickel and chromium plating, owing to the danger of producing stains and passivation, resisting chromium plating if left exposed to air very long.

By Willis M. Peirce
Chief of Research Division
New Jersey Zinc Co.
Palmerton, Pa.

Progress in zinc coating & electro-galvanizing of sheet and wire

SINCE NEARLY HALF the zinc produced in the United States is used for galvanizing, it is to be expected that the prosperity of the entire zinc industry is dependent to a very considerable degree on the production and consumption of galvanized wire, sheet and other items of hardware. It is also natural that the American Zinc Institute, which is concerned primarily with the economic side of the industry, should pay much attention to the production as well as promotion and sale of satisfactory galvanized ware.

In celebrating its 20th anniversary at a meeting in St. Louis this spring, the guest of honor was its first president, Charles T. Orr. In brief reminiscent remarks he recalled that the first treasurer, Howard I. Young, is now president, having served the Institute continuously in some official capacity throughout its existence. Moreover, he pointed out that Walter R. Ingalls, a foremost authority on zinc, was again to address the Institute on the "Situation in Zinc" as he had in 1918, and a comparison of the predictions made in that earlier address with subsequent events establish Mr. Ingalls as something of a prophet. The latter's paper emphasized the importance of the international

metal market on the industry in the United States, and how such unpredictable factors as the 1937 drought could cause major upsets in the raw material markets.

All society meetings must have their business sessions and officers' reports, but we have never before seen a secretary's report dramatized and transmitted into a highlight of the meeting. By portraying a budget meeting, the secretary's staff in an acrimonious ten minutes gave a vivid picture of the past and hoped-for future of one of their major activities, the promotion of zinc coatings.

The Institute, inspired by its natural desire to sell more zinc for zinc coatings, has conducted an active campaign to educate the consumer as to the value of galvanizing and particularly the increased economy of heavy zinc coatings. The "Seal of Quality" brand of the American Zinc Institute is used by many steel companies to identify a product with a guaranteed weight of coating. Recognizing that the production of heavy coatings presents technical problems in the shops of the galvanizer, particularly in securing adherence and uniformity of coating together with increased thickness, the Zinc Institute two years ago sponsored the formation of the Galvanizers' Committee, composed exclusively of galvanizers and meeting in closed session for the free discussion of their problems. A report of their proceedings, interesting as it undoubtedly would be if available, is not nearly so important as the fact that such meetings are held.

The program to promote the use of zinc coatings concentrates on an educational campaign among farmers, who constitute perhaps the largest potential market for galvanized sheet and wire. A single example will illustrate the possibilities in this field: If one fifth of the farmers known to raise poultry were

to build the smallest poultry house of practical size using a newly developed type of construction employing wood framing, pressed board insulation and 28-gage corrugated "Seal of Quality" sheathing, it would require 250,000 tons of galvanized steel, and 30,000 tons of zinc would be used for the coating. The factor that can convert such a dream to a reality is that the farmers would save money as compared to the usual type of all-wood construction. (Sta-

tistics on the annual per capita consumption of chickens necessary to pay for this program are available on request!)

A group of papers relating to various phases of galvanizing completed the technical program. As is well known, the demand for increasingly heavy and more adherent coatings, coupled with advances in the art of rapidly applying smooth, heavy deposits of zinc, have led to important developments in the field of

Pickling and Washing Plant for Electrical Conduit at Youngstown Sheet and Tube Co. Heavy scale and rust is to be avoided on ware designed for galvanizing; after cleaning, such a surface is rough, porous and prone to produce a brittle coating



electro-galvanizing. Taking advantage of the knowledge that with very pure electrolyte a high current density may be employed and smooth deposits produced of any thickness needed as a protective coating, processes have been developed deriving their zinc either from ore or from metallic zinc anodes. So far these processes have attained commercial importance only in the case of wire coating (see METAL PROGRESS, May 1937, p. 524), but extension into the sheet field is in course of development.

The outstanding advantage of electro-galvanizing as compared with hot-dip galvanizing is the combination of excellent adherence and very heavy coating obtainable. Ease and precision of control of the weight of coating is also important. Striking as the progress has been, it is certain that further progress may be expected along such lines as the composition of electrolyte and anodes.

While the electro-galvanizing method has important points in its favor, the low initial cost of hot-galvanizing equipment, the fact that such equipment now exists in most plants, and the known and probably lower operating cost offer a great incentive to improve hot-galvanizing methods to meet present market demands in the wire field. In the sheet field no method has yet seriously challenged hot-dipping.

Speeding the Hot-Dipping Process

There is considerable knowledge available which has not been fully utilized in the improvement of the hot-dipping process. Adherence of heavy hot-dipped coatings is known to be improved by using pure zinc and by reducing the iron-zinc alloy which forms next to the steel to the thinnest and most uniform layer possible. The smoother the steel, the better this can be obtained. This points toward the use of freshly rolled sheets requiring a minimum of pickling. Alloying of the zinc also offers possibilities which will doubtless be exploited when the fluxing problems introduced by changes in the composition of the zinc are overcome. It is known, for example, that aluminum radically affects the formation of iron-zinc alloy between the steel sheet and the zinc coating, but that it must be used in a properly formulated alloy to secure good corrosion resistance.

Many of the problems of galvanizing reside in the condition of the steel surface and the difficulty of maintaining satisfactory entrance

and exit fluxes on the zinc bath. *Adherence* is influenced by the inner iron-zinc layer and by the ductility or toughness of the outer zinc layer — both essentially resembling castings.

The iron-zinc alloy layer may be reduced to a comparatively thin film by methods mentioned just above, together with effective washing of the cleaned sheets immediately prior to immersion to remove any iron salts or sponge iron. Not only is less alloy formed but the boundary between the alloy layer and the zinc coating approaches a straight line instead of being very irregular, with jagged points of alloy notching the under side of the zinc coating and affording starting points for cracks when the coating is bent.

If such a sheet is prepared, the time of immersion in the zinc bath can be very short indeed, especially if the flux is 25% zinc chloride rather than the usual hydrochloric acid flux. This eliminates the necessity for reconverting any iron chloride back to metallic iron, which forms dross and zinc chloride, the latter then acting as the necessary flux — all of this absorbing heat and taking time, to say nothing of producing unnecessary dross. This is the rather simple theory back of the known fact that adherence is greatly improved by galvanizing a freshly rolled sheet or drawn wire with a minimum of pickling, thorough washing, a zinc chloride flux, and minimum immersion.

Composition of the commercial zinc now used has small influence on the thickness or character of the alloy layer; however, it does influence the toughness and ductility of the surface layers. Cadmium, which is virtually absent in high purity zinc, embrittles a cast zinc structure and is present in sufficient quantity in most commercial grades of zinc to increase the tendency of the coating to crack when bent. Now it is a peculiar circumstance that the fluxes based on zinc-ammonium chloride, which are exclusively used in galvanizing and for which no substitute seems to have been found in spite of a considerable amount of research, perform without difficulty only when some lead and cadmium are present in the zinc and so introduce traces of lead and cadmium chlorides into the flux.

Inasmuch as so much careful study is being given to all branches of the art of coating metal with zinc, it may be confidently expected that the future will bring forth real advances in application of zinc coatings by hot-dipping, spraying and electrodeposition.

By Edmund R. Thews

Abstracted from *The Metallurgist*, supplement to *The Engineer*, April 29, 1938, page 114

Sorting unknown light alloys

IDENTIFICATION of light metal scrap is more difficult than similar work on other alloys since there is practically no difference in appearance or fracture. Furthermore, aluminum and magnesium alloys as a whole are much more subdivided into chief and side groups than the industrial copper alloys, while the range of composition within these numerous groups is much wider, as a rule, and much less clearly defined. For instance, light metal pistons may be composed of widely varying aluminum or magnesium alloys; while the magnesium alloy pistons are of rather uniform composition, those of aluminum alloys may contain alternatively copper, silicon, nickel, or magnesium.

Intelligent sorting may fortunately be done by rapid chemical means, as represented by simple drop tests, based on the fact that if a drop of definitely composed solution is placed on a clean spot on the metal, it will give certain reactions indicating the presence of appreciable percentages of certain elements in the light metal tested.

The four solutions used for this purpose may conveniently be kept in individual bottles marked (for use by the workman) with numbers or colors, and the sorter is instructed accordingly:

Solution No. 1—30% nitric acid in water.

Solution No. 2—20% caustic soda solution

(20 gr. of caustic soda sticks in 80 cc. of water).

Solution No. 3—5% hydrochloric acid solution in water.

Solution No. 4—5% cadmium sulphate solution (5 gr. cadmium sulphate in 95 cc. water).

From the accompanying table it is seen that No. 1 identifies magnesium alloys by a white coloration in 5 min., accompanied by a distinct development of gas noticeable through the formation of tiny bubbles within the drop. Confirmation is had by resistance to solution No. 2 and the relatively light weight.

If, on testing the unknown metal with a drop of the solution No. 2, a white coloration is obtained, the piece may be aluminum, Al-Mg, or Al-Mg-Mn. Commercially pure aluminum is indicated if no etching reaction is obtained with the solutions No. 1, 3, and 4. Al-Mg and Al-Mg-Mn alloys are colored gray after 8 to 10 min. by solution No. 4. While no ready means of separation is shown, the difference in their technical properties is not so considerable, and a certain amount of the latter alloys can even be added to the former, as the Al-Mg alloys go fairly well with a limited percentage of manganese. However, their good corrosion resistance would be spoiled by mixing with any alloys containing copper.

If solution No. 2 produces a black stain, the alloys containing copper (Al-Cu, Al-Cu-Zn, and Al-Cu-Ni) are indicated. If, on wiping off the remaining caustic soda solution, a drop of the solution No. 3 removes the black stain, the scrap tested belongs to the group Al-Cu-Zn, which is further distinguished from the other two groups of Al-Cu alloys by a gray stain caused by a drop of solution No. 4. The two groups Al-Cu and Al-Cu-Ni cannot be distinguished from one another by the drop test, but mixing of these two groups does not produce any harm outside of diluting the nickel contents.

If a drop of solution No. 2 produces a pure gray stain on the clean metallic surface, the group Al-Si-Cu is indicated, the gray spot remaining if (after removing the caustic solution) it is covered with a drop of solution No. 3.

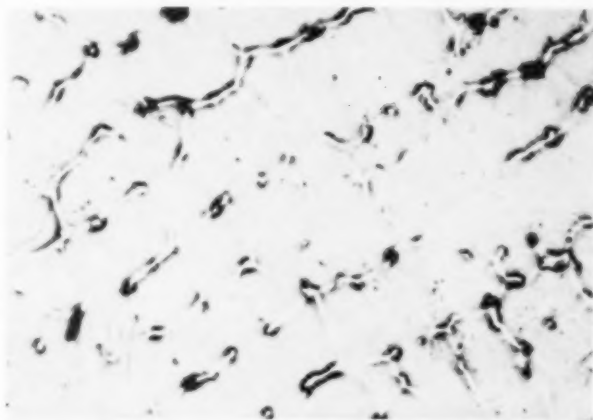
The alloys Al-Si, Al-Si-Mg, and Al-Mg-Si are indicated by a grayish-brown coloration under a drop of solution No. 2. The Al-Mg-Si alloy is distinguished from the other two by the removal of this stain under a drop of solution No. 3 (after removal of the caustic solution No. 2).

Reactions in Drop Tests

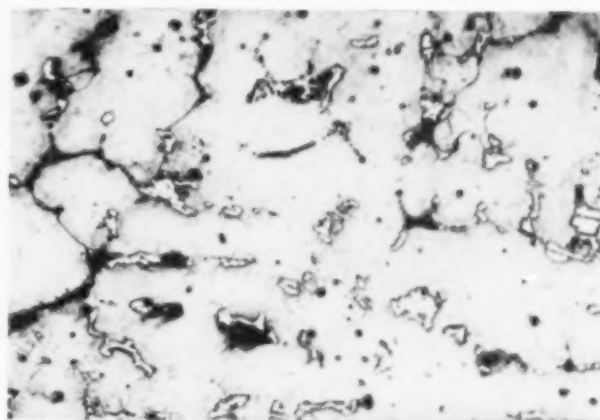
ALLOYS	SOLUTION NO.			
	1	2	3	4
Al	None	White	—	None
Al-Cu	None	Black	Black remains	—
Al-Cu-Ni	None	Black	Black remains	—
Al-Cu-Zn	None	Black	Black removed	Gray
Al-Si	None	Grayish-brown	Color remains	—
Al-Si-Cu	None	Gray	Color remains	—
Al-Si-Mg	None	Grayish-brown	Color remains	—
Al-Mg	None	White	—	Gray
Al-Mg-Si	None	Grayish-brown	Color removed	—
Al-Mg-Mn	None	White	—	Gray
Mg	White	None	—	—

Microstructure of Nickel-Copper Alloys

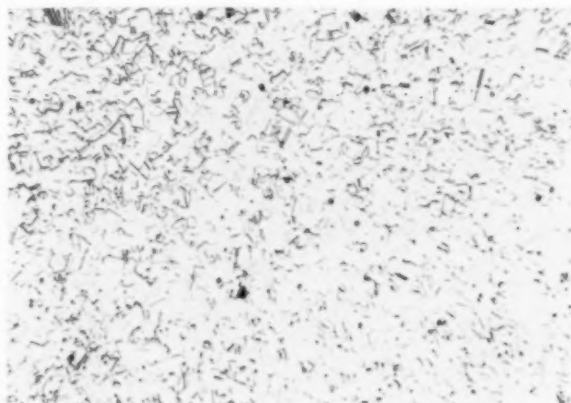
Photomicrographs by Research Laboratory, International Nickel Co.



Cast 1 1/2-In. Monel Bar; Brinell 117
Ni 67, Cu 29.5, Fe 2.0, Si 1.5, C 0.20



Cast 1 1/2-In. Silicon-Monel Bar; Brinell 327
Ni 58.5, Cu 34.18, Fe 3.3, Si 3.95

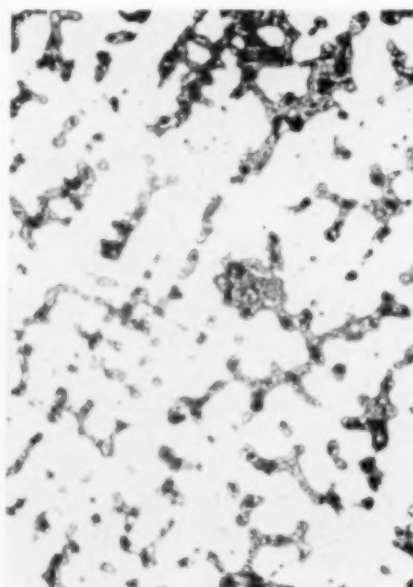


Monel Metal, Hot Rolled



Monel Metal, Cold Rolled and Annealed

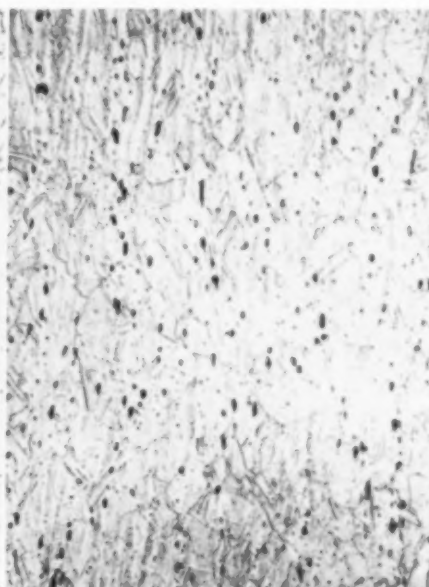
Monel Metal at 100 Diameters; Etched in 50-50 Nitric-Acetic Acids



Cast Ingot for Sanitary Ware
Ni 20, Zn 6, Cu 65, Sn 4, Pb 5



Hot Rolled Condenser Tube
Ni 20, Zn 5, Cu 75



Cold Drawn (Leaded) Screw Stock
Ni 18, Zn 20, Cu 61, Pb 1

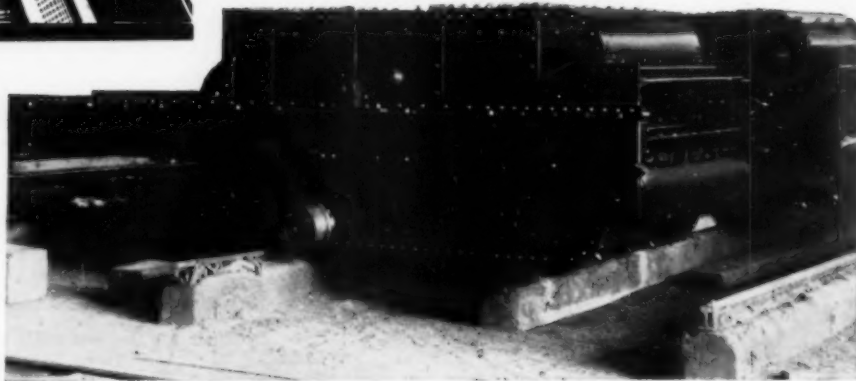
High "Nickel-Silver" at 100 Diameters; Etched in 10% KCN plus 1% H₂O₂



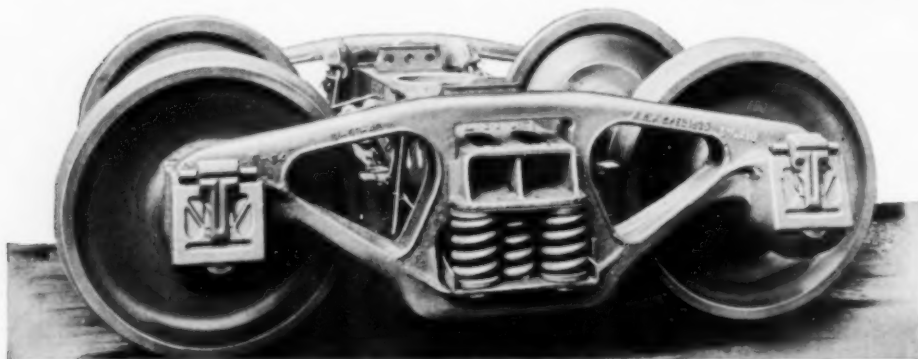
BIGGER PAY LOADS

*without increasing
power costs*

● This sturdy Nickel Alloy Steel ore carrier, weighing 12,000 lbs. unloaded, has replaced a carbon steel skip weighing 15,000 lbs. The saving of 3000 lbs. in dead-weight has been translated into greater pay load capacity, raising the hoisting capacity from 19,000 lbs. to 22,000 lbs. without increasing power costs. The high strength-weight ratio of the Nickel Alloy Steels, combined with their unusual toughness, make it possible to increase the capacity of haulage equipment of many types without increasing weight.



NICKEL ALLOY STEELS



● The side frames and bolster castings of this hopper car truck were made of Nickel Steel, effecting a saving of 20% in the weight of trucks without decrease in the required properties of strength and toughness. Our engineers will be glad to consult with you and to suggest how the Nickel Alloy Steels will save you money.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

Correspondence and foreign letters

A Plea for an International Committee on Nomenclature

CAMBRIDGE, *Mass.* — It must be apparent to American students of metallography that a schism has developed in their ranks which, if not promptly healed, will confuse and disconcert new adepts in this important field.

I have more especially in mind the differences of opinion held by certain groups as to the meanings which should be attached to the terms pearlite, sorbite, and troostite.

In 1910 a committee was organized by the International Association for the Testing of Materials to consider "the nomenclature of the microscopic substances and structures of steel and cast iron." This committee was composed of the following members: H. M. Howe (United States) Chairman, F. Osmond (France), H. C. H. Carpenter (England), W. Campbell (United States), C. Benedicks (Sweden), F. Wüst (Germany), A. Stansfield (Canada), J. E. Stead (England), L. Guillet (France), E. Heyn (Germany), W. Rosenhain (England), and A. Sauveur (United States) Secretary.

In its report presented in 1912 the committee defined pearlite in the following terms: "The iron-carbon eutectoid consisting of alternate masses of ferrite and cementite. A conglomerate of about 6 parts of ferrite and 1 of cementite.

When pure, contains about 0.90% of carbon, 99.10% of iron."

The definition implied that pearlite was that constituent, approximately eutectoid in composition and clearly lamellar in structure, resulting from the slow cooling of iron-carbon alloys through their thermal critical ranges. It was the product of the slow transformation of austenite of eutectoid composition. If austenite was not originally of eutectoid composition, then not until it had reached that composition through the rejection of ferrite or of cementite would pearlite form. All of this was in agreement with our understanding of the teaching of the equilibrium diagram.

This conception of the nature of pearlite was universally accepted and remained unchallenged for a quarter of a century.

In recent years, however, some writers have proposed to describe as pearlite all aggregates of ferrite and cementite, with the exception of martensite, resulting from the cooling of austenite to room temperature quite regardless of the carbon content and microstructure of these aggregates. In other words, they now propose to describe as pearlite those structures or constituents which in the past had been designated as troostite and sorbite. To illustrate: Steel containing some 0.40% carbon cooled in air from its austenitic range, so generally considered as sorbitic, is described by them as consisting of pearlite, although that pearlite would contain but one half the normal amount of carbon present in the eutectoid and be very imperfectly lamellar, and that only in spots. Its ferrite lamellae would have to be some fourteen times thicker than its cementite lamellae.

In an attempt to show that pearlite is not necessarily of eutectoid composition, it is sometimes pointed out that iron-carbon alloys containing considerably less carbon or considerably more carbon than the eutectoid, possibly as little as 0.75% or as much as 0.95%, appear under microscopical examination to be wholly pearlitic. This I believe to be due chiefly to the

difficulty of detecting the occurrence of small amounts of ferrite or of cementite and does not affect the soundness of the definition proposed by the committee.

To have certain authoritative writers refer to some microstructures of steel as consisting of pearlite while other no less authoritative writers describe them as sorbite or troostite should not be tolerated.

We should speak the same language, but it is not for any one of us, nor for any small group, or even for any large group to decide what that language should be. It must be an universal language and not a Yankee dialect, unless indeed the Yankee dialect is adopted as the universal language. There is no room here for arbitrariness, sophistry, or provincialism.

So important a matter can only be decided by an international committee made up of outstanding metallurgists representing the various countries in which metallographic studies are actively pursued.

ALBERT SAUVEUR
Professor of Metallurgy (Emeritus)
Harvard University

High Phosphorus Steels

COLUMBUS, Ohio — In the February issue of METAL PROGRESS, in his letter relative to high tensile structural steels used in England, Mr. Monypenny indicated that phosphorus is looked upon in that country either as a dangerous impurity or as an element conferring but small benefits to high strength steel. Quite a different attitude is taken by our own engineers and metallurgists. Phosphorus contents in low alloy, high strength steels above the ordinary limits for tonnage steels have received general acceptance in this country for two very good reasons.

One reason for adding phosphorus is to raise the yield point, for American steels are primarily steels with high yield point. This is because, for a given percentage, added phosphorus is by far the most effective of the common alloying elements for raising the yield strength. Epstein, Nead, and Halley, in the paper "Choosing a Composition for Low Alloy, High Strength Steel," *Transactions A.I.M.E., Iron and Steel Division*, 1936, page 309, indicated the effects of single elements on the yield and tensile strength of steel after cooling in air. From their information one finds that each

0.10% phosphorus increases the yield point of steel about 7000 psi., and that in order to obtain an equal effect from other elements requires either 0.40% carbon, 0.70% copper, 0.90% manganese, 0.60% chromium, 1.6% nickel, 1.0% silicon, or 0.75% molybdenum. These figures are, of course, merely indicative and will differ with changes in treatment of the steels or with different combinations of elements or between results of different investigators. Nevertheless, they do serve to illustrate the very marked effect of phosphorus on yield point.

Provided the carbon content of the steel is low, phosphorus contents of the order of 0.10 to 0.20% are found very useful in low alloy, high strength steels and are being effectively utilized. A low carbon content assures freedom from phosphorus embrittlement, an effect which does not become serious in low carbon steel until phosphorus exceeds about 0.25%. Chromium, molybdenum, aluminum, and to some degree copper were demonstrated to offset phosphorus embrittlement; thus, those steels containing one or more of these are more immune from the embrittling effect of phosphorus.

In this country, in contrast to the English practice, it is aimed to keep the carbon low and to gain strength, yield, ductility, and corrosion resistance with elements other than carbon to avoid some of the difficulties met with carbon, particularly as regards air-hardening tendencies and welding troubles. Phosphorus has proved an excellent element to use in place of carbon.

The second major reason for adding phosphorus is to increase corrosion resistance. Apparently doubt still exists in the minds of some English metallurgists and engineers as to the claim for better corrosion resistance from phosphorus. This impression may have grown out of the paper by J. A. Jones on "The Effect of Phosphorus on the Mechanical and Corrosion Resisting Properties of Low Carbon and Low Alloy Structural Steels," in the *Journal of the Iron and Steel Institute*, 1937, page 113, in which it is concluded that no evidence had been found to indicate that a high phosphorus content confers on the steel any useful increase in resistance to corrosion. This rather sweeping conclusion was made after exposing a series of steels to atmosphere for a period of only 28 days. Such a short exposure rarely gives more than an indication of the effect of composition changes and certainly is worthless for comparing the relative corrosion resistance of low alloy steels, since it often requires several times as long for the

more protective rust layers on the alloyed steels to develop and become effective.

Dr. Saklatwalla, in a discussion of Jones' paper, presented the American viewpoint on the effect of phosphorus in steel on corrosion resistance very well indeed and demonstrated beyond question that phosphorus, whether used singly or with other elements, promotes resistance to corrosion in atmosphere and in salt spray to a remarkable degree. His data may be supplemented by other atmospheric corrosion data obtained at Battelle Memorial Institute for

Saklatwalla's Cr-Cu-Si-P steel shows a greater effect of phosphorus in increasing the corrosion resistance after exposures of 1½ years (corrodibility index 32) than the Cr-Cu-Si-P steels exposed by us at Battelle (corrodibility index between 52 and 59 for the same period).

This greater corrosion resistance of the commercial American Cr-Cu-Si-P steels is due to their much lower carbon and manganese contents, practically being one-half the carbon and manganese contents of the Battelle steels. Carbon and manganese are held to these low

Corrosion Data for High and Low Phosphorus Steels

Type	Chemical Analysis							6 Months		12 Months		18 Months		24 Months		
	C	Mn	P	Si	S	Cu	Cr	Loss	Index	Loss	Index	Loss	Index	Loss	Index	
22-Gage Sheet Steels Exposed to Atmosphere in Columbus, Ohio																
Ingot iron	0.05	0.12	0.006	0.02	0.04	—	—	20.6	100	31.2	100	53.9	100	61.2	100	
Iron, 0.12 P	0.05	0.10	0.12	0.01	0.04	—	—	18.5	90	26.2	84	41.9	77.5	47.7	78	
do., 0.21 P	0.04	0.12	0.21	0.01	0.034	—	—	17.6	85.5	25.8	82.5	38.2	71.0	41.4	67.5	
Carbon steel	0.13	0.58	0.008	0.09	0.039	—	—	20.5	100	32.1	103	55.7	103	62.0	102.0	
C-P	0.12	0.50	0.17	0.10	0.04	—	—	17.1	83	25.1	80	38.0	70.5	45.6	74.5	
C-Si	0.12	0.50	0.008	0.41	0.04	—	—	20.0	97	29.6	95	54.3	101	61.4	100.5	
C-Si-P	0.11	0.50	0.18	0.40	0.04	—	—	17.2	83.5	24.5	78.5	36.8	68	42.5	69.5	
C-Cu	0.15	0.45	0.008	0.10	0.04	0.35	—	19.4	94	26.2	84	43.6	81	49.4	81.0	
C-Cu-P	0.14	0.45	0.17	0.10	0.04	0.35	—	16.7	81	23.0	73.5	36.2	67	43.8	71.5	
C-Cr	0.12	0.57	0.006	0.02	0.04	—	0.46	22.8	111	34.7	111	55.5	103	70.4	115	
C-Cr-P	0.13	0.60	0.19	0.02	0.04	—	0.43	18.0	87.5	25.8	82.5	37.1	69	43.4	71.0	
C-Cr	0.14	0.52	0.007	0.01	0.04	—	0.94	23.6	114	38.0	122	54.9	102	69.1	113.0	
C-Cr-P	0.13	0.50	0.18	0.01	0.04	—	0.95	18.9	92	25.6	82.0	38.3	71	48.3	79.0	
C-Cr-Si-Cu	0.15	0.60	0.016	1.07	0.04	0.37	0.97	19.3	92.5	27.2	87	34.7	64.5	40.6	66.5	
C-Cr-Si-Cu-P	0.17	0.59	0.12	1.00	0.04	0.37	0.95	18.2	88.5	25.9	83	31.7	59	35.4	58.0	
C-Cr-Si-Cu-P	0.14	0.60	0.21	1.00	0.04	0.37	0.95	16.7	81.0	23.1	74	29.9	55.5	32.7	53.5	
C-Cr-Si-Cu-P	0.16	0.60	0.32	1.00	0.04	0.37	0.95	16.5	80.0	22.7	72.5	28.1	52	30.9	50.5	
Steels Quoted by Saklatwalla, Figured on Same Basis																
Open-hearth	0.02 Cu	0.04	0.22	0.010	0.002	0.037	0.018	0.009	90.4	100	135.6	100	161.5	100	180.8	100
	0.05 Cu	0.16	0.18	0.004	0.004	0.031	0.052	0.015	77.5	86	116.3	86	135.6	84	148.6	82
	0.07 Cu	0.09	0.51	0.069	0.005	0.028	0.07	0.117	64.6	71	96.9	71	116.3	72	122.7	70
	0.25 Cu	0.065	0.49	0.052	0.005	0.022	0.25	—	58.1	64	90.4	70	103.4	64	109.8	61
Cr-Cu-Si	0.07	0.38	0.009	0.79	0.017	1.03	1.52	51.7	57	71.05	52	83.9	52	90.4	50	
Cr-Cu-Si	0.085	0.38	0.033	0.78	0.020	0.53	1.42	51.7	57	71.05	52	77.5	50	83.9	47	
Cr-Cu-Si-P	0.02	0.38	0.151	0.82	0.023	0.58	1.05	38.7	43	45.2	33	51.7	32	58.1	32	

Monsanto Chemical Co. covering a two-year exposure period, such data being given in the adjoining table. (In this table, Saklatwalla's results from his "Fig. B" are figured on the basis that the corrodibility index for the 0.02% copper openhearth steel is 100%.)

Thus, phosphorus has a very potent influence on decreasing corrosion, especially in the presence of other alloying elements. It should be noted from these data that the protective effect of phosphorus has asserted itself in six months and that this protection continues to improve with time.

values in commercial steels not only for preventing corrodibility due both to carbon and to manganese, which fact is well known, but also to obtain better ductility and weldability.

In view of results with phosphorus-bearing steels in this country, it would seem that one need no longer fear this element, provided its percentage range is held within limits and the carbon and alloy contents of the steel are balanced properly.

C. H. LORIG

Battelle Memorial Institute
for Industrial & Scientific Research

Effect of Scratches and Abrasions on Corrodibility of Stainless Steel

PARIS, France — It is a well-known fact that the high chromium stainless steels owe their remarkable resistance to an oxidizing atmosphere to the formation of a protective surface film that is continuous, impermeable, adherent and invisible. This phenomenon is sometimes called "passivation"; it may be induced or increased by means of a chemical treatment such as pickling in an oxidizing reagent like aqua regia. The antithesis of the passive state is called the active state.

Passivation, however, disappears in non-oxidizing acid solutions such as sulphuric acid and this "de-passivation," examined by potentiometric methods, may be used as a new means of studying protective coatings, as shown by M. Guillon in his recent thesis at Grenoble, 1936. He particularly showed the self-passivation of stainless steel after a simple exposure to air.

It confers on stainless steel a better chemical resistance and at the same time reduces its surface tension.

Thus, a 0.1% C, 13% Cr steel in the active state loses 9 mg. per sq.cm. after 48 hr. in a 10% citric acid solution, but there was no measurable loss in weight when similarly immersed after a 48-hr. passivation in air.

A surface that is not greasy and completely active is wetted with water. Upon a surface thoroughly cleaned of grease, the "wetting ability" is a sign of activity. On the other hand, progressive passivation varies the size of the droplets deposited in wet iodine atmosphere.

It has been shown that the rate of self-passivation is dependent on the humidity of the air and the chromium content of the steel, so that metallographic polishing, so often carried out by the use of alumina in a damp atmosphere, provokes passivation, although to a variable extent. In the first place, the more reactive "Beilby layer" should become passive more rapidly, and in the second place, two factors act in opposition upon the metallic surface — the passivating contact of aerated water and the activating abrasion of the alumina grains.

This latter influence is illustrated by the effect of acidified cupric reagents such as Marble's reagent (25 cc. HCl, 10 g. CuSO_4 , 25 cc. H_2O) upon passive surfaces. These surfaces are finely pitted, the number of pits rapidly increasing. At a magnification of 1150 diameters (Fig.

1) it can be seen that these pits are lined up in straight lines, some of which are marked by fine polishing scratches, while others show no marks. It can therefore be assumed that finishing promotes corrosion, corrosion only beginning when the film breaks at a weak point.

Passivation may also sometimes vary from one constituent of the metal to the other, affecting the ultimate corrosion. The following may be cited as an example:

A stainless steel containing 0.1% C, 24% Cr and 8% Ni is formed of two constituents — austenite and ferrite. A 10% hydrochloric acid solution outlines the ferrite; on longer etching, general dissolution of the two constituents occurs, the ferrite being attacked more rapidly than the austenite (Fig. 2). If the surface of the sample is previously subjected to the action of a passivating medium, partial corrosion of the ferrite occurs after 5 min. (Fig. 3), the austenite remaining unattacked. On further etching, the ferrite appears black on white (Fig. 4).

Thus, there are two distinct phenomena: First, the passivation differentiates the two constituents, the one being attacked, the other remaining unaffected. In the active state the two constituents possessed similar electrochemical potentials; after passivation the potentials become electropositive, but if one of the constituents oxidizes more rapidly than the other, its potential may become definitely more electropositive than the potential of the one oxidizing less rapidly, and will provoke corrosion by galvanic action. In the second place, corrosion is initially indicated by pinpoint spots resembling etching pits; it almost seems as though the protective film were being broken at a rapidly increasing number of points.

Passivation, either by nitric acid or in air, may completely modify the action under metallographic attack. Thus:

1. A 30% chromium ferritic steel, etched in 10% hydrochloric acid, shows ferrite and carbides in the active state, and micro-pits lined up along the scratches in the passive state (Fig. 5 and 6).

2. An 18-8 austenitic steel etched in Marble's reagent shows austenite in the active state and micro-pits in straight lines in the passive state (Fig. 7 and 8).

These considerations concerning self-passivation are of more than usual interest since they lead to practical consequences.

For instance, the corrosion resistance of 18-8 stainless steels depends largely on the



Fig. 1; $\times 1150$
Passive steel etched
with acidified cupric
reagent (Marble's)

Fig. 2; $\times 250$
Active state;
phases outlined

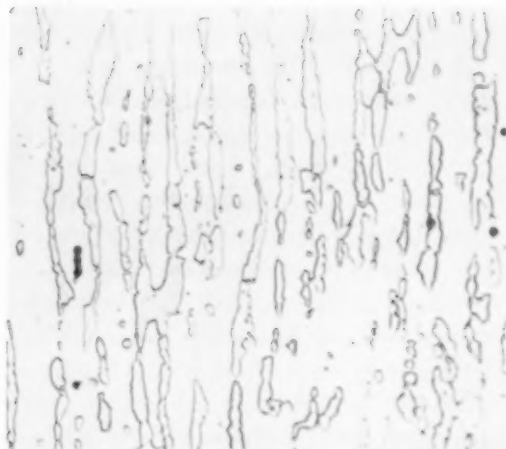


Fig. 2, 3 & 4
Two-phase steel
0.1% C, 24% Cr, 8% Ni
Etched in 10% HCl

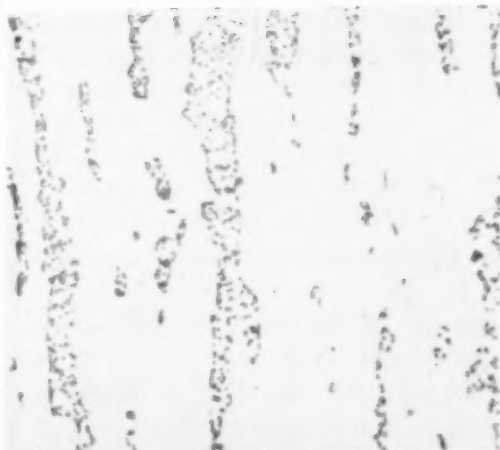


Fig. 3; $\times 700$
Passivated by air;
ferrite locally
attacked

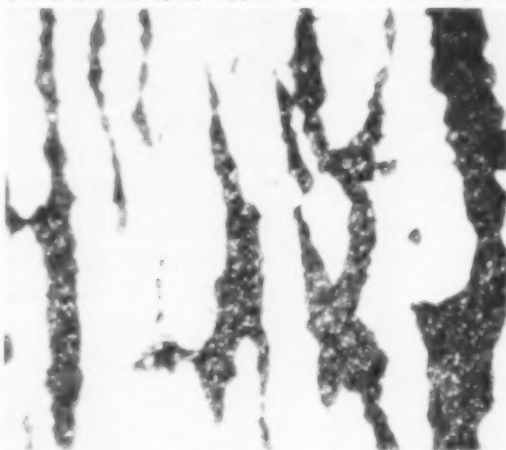


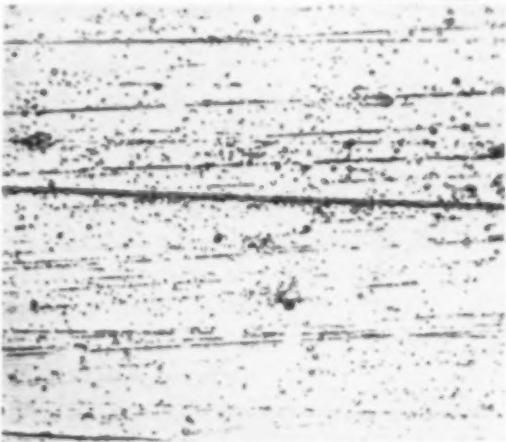
Fig. 4; $\times 700$
Passivated by air;
austenite unetched
after long attack



Fig. 5; $\times 600$
Active state

Fig. 6; $\times 600$
Passive state

27% Cr, 0.2% C alloy
(ferrite plus carbides)
Etched in 10% HCl



Etching that shows
structure on
activated surface
merely pits
along polish furrows
on passive surface

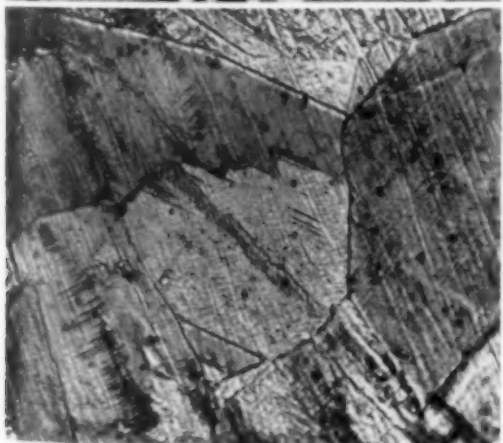
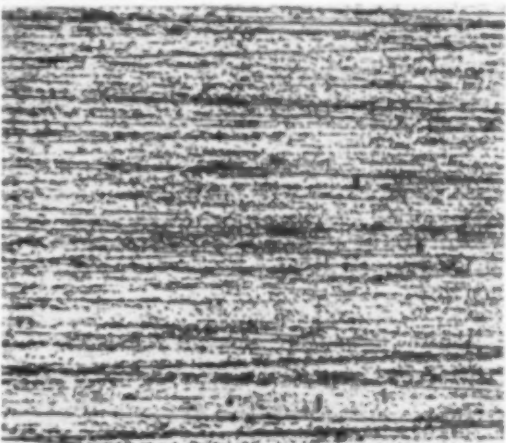


Fig. 7; $\times 600$
Active state

Fig. 8; $\times 600$
Passive state

18% Cr, 8% Ni
(austenitic alloy)
Etched in
Marble's reagent



Passive Surfaces on Stainless Steel Corrode by Pitting Attack Favoring Strained Areas or Microconstituent

quality of the superficial passivation acquired before its introduction into the corrosive medium, when this medium is not passivating. This is the case, for instance, in sea water and marine atmosphere; the passivity of the metal depends, as we have just seen, on the finishing and pickling operations to which the pieces were subjected and on the manner in which the surface is maintained.

Any surface defect, scratch, flaw, or inclusion may modify locally the condition of passivation and also act as a center of condensation and accumulation of corrosive droplets. This may account for the origin of pitting corrosion often observed in the depressions and edges of decorative motifs.

In marine applications care must be taken to avoid activating polished surfaces placed in corrosive atmospheres. Many polishing materials are abrasive and de-passivate the surfaces; this is an important consideration in the maintenance of decorative parts and ship's furnishings. Since the surrounding medium is not passivating, parts on shipboard made of ordinary stainless steel should either be preserved by washing and drying—a prescription long followed for stainless steel knives—or else recourse can be had to the use of preservative passivating agents.

ALBERT PORTEVIN

Ancien Président de la
Société des Ingénieurs Civils de France

Nickel Catalyst for Re-forming Gas-Air Mixtures

BERKELEY, Calif. — Since publication of an abstract from Bulletin No. 396 of the Bureau of Mines on Sponge Iron (METAL PROGRESS for June) an inquiry has been received for more information on the catalyst used in the gas converter. The following details may therefore be placed on record:

In our earlier experiments at Berkeley we made "mud pies" of Norton RA-562 cement. These pats of plastic material were rolled out on waxed paper until they were approximately $\frac{1}{4}$ to $\frac{3}{8}$ in. thick, and then lightly scored with a spatula. Thereafter they were dried and burned at a temperature sufficiently high to insure good bonding of the refractory. After burning and cooling they were immersed in a nearly saturated solution of nickel nitrate and allowed to soak for a short time. The excess nickel nitrate solution was drained off and the wet granules

calcined at a temperature of about 1300° F. They were inserted into the catalytic chamber with the nickel in form of oxide, but the reduction to metallic nickel occurs in a few minutes.

In the larger unit at Martinez, the Mountain Copper Co. purchased from the Norton Co. a number of bags of broken refractory furnace liner, which were put through coarse crushing rolls and sized material screened therefrom.

At one time we carried on a lot of work on the catalyst itself, and found that this simple and direct method could hardly be improved upon, nor was it profitable to attempt to add "promoters" of any type, since the activity of the nickel deposited upon the alundum grains was extremely high. I might add that in the Martinez unit the gas was in contact with the catalyst itself for a period of time which we estimated to be from $\frac{1}{5}$ to $\frac{1}{2}$ of a second. The bell-shaped receptacle for the catalyst was approximately 18 to 20 in. in diameter at the large end, and 24 in. deep, and produced gas equivalent to an input of 60,000 cu.ft. of methane per day. This corresponds to something like 200,000 to 300,000 cu.ft. of re-formed gas per day, high in CO and H₂ and low in CO₂ and H₂O. The capacity is limited only by the economical pressure drop allowable in the bed of granular catalyst.

Our contribution to the art of re-forming gas consisted in devising an apparatus and technique of thermal balance which permitted large-scale operation without difficult or insuperable problems of heat transfer. The significant factors which must be maintained, or conditions avoided, to insure satisfactory operation of this type of catalyst are:

1. Suitable adjustment of the preheat temperature.
2. Avoidance of any "dead spaces" in the gas stream; that is, a continuously enlarging cross section of flow.
3. Mixing the gases at temperatures above or equal to the ignition temperature of methane-air mixtures under these conditions of composition (approximately 1450° F.) and maintaining the velocity of flow over the catalyst sufficiently great to prevent flame or combustion other than surface catalysis.
4. Control of the thermal balance of the unit in such a way that the reactions are thermally self-balancing.

From our experience I feel quite sure that this method of reforming mixtures of natural gas and air (or mixtures of other hydrocarbons

and air) is far superior from a practical viewpoint to any other method with which I am familiar. From the standpoint of first cost and extremely large output per unit of volume, I do not believe that alternative methods can compare with the one described in Bulletin No. 396.

I trust it will not decrease interest in this method of re-forming gas that both the apparatus and the method have been patented. These patents were originally assigned to the Mountain Copper Co., in view of the Bureau of Mines' cooperative agreement, but when the project was discontinued they were reassigned to me. I have no exaggerated idea as to their value, and have already licensed certain local organizations to utilize them for gas-making purposes.

CHARLES G. MAIER

Bureau of Mines, Experiment Station
University of California

Heat Treatment of Cast Iron

LAFAYETTE, Indiana—A remark made by Duncan P. Forbes in his article on "New Cast Irons, Heat Treated, Rolled" in the February issue of METAL PROGRESS, probably requires a little modification. He writes on page 139:

"Cast iron is an extremely high carbon material. Furthermore, the graphite being exposed on the surface of the metal permits decarburization to proceed at a very rapid rate. The so-called reducing atmospheres of many heat treating furnaces actually are oxidizing to the graphite and the combined carbon of the cast iron. Even an atmosphere mildly carburizing to soft steel can decarburize cast iron."

To call reducing atmospheres "oxidizing" is somewhat ambiguous. What Mr. Forbes no doubt meant was that the total carbon, composed of the graphitic and combined types, is removed, leaving spongy soft ferrite. Hydrogen in a reducing atmosphere will form methane from carbon in iron, according to the reaction



We have supervised the hardening of many tons of cast iron, both plain and alloyed. Sections varied from $\frac{1}{4}$ to 1 in. thick and quenching temperatures ranged from 1560 to 1640° F. depending on the section and composition. We found that slightly oxidizing atmospheres could be depended upon for much greater uniformity in final hardness than reducing atmospheres. Quenching from cyanide baths also did not give

as great surface hardnesses as did an open-fired furnace, but this probably is because the film of molten cyanide adhering to the casting does not dissolve readily in oil and hence the initial rate of cooling is not high enough to obtain maximum hardness.

In oxidizing atmospheres a thin film of oxide, or scale, is produced as soon as the surface of the casting reaches the vicinity of the critical temperature. This coating of scale greatly retards subsurface oxidation so that after quenching in oil, a large part of the scale flakes off leaving fully hardened iron below it. Those parts which gave low hardness readings on the first inspection were given a light grind (0.005 to 0.010 in.) on one end or side and re-inspected, and more than 95% of the ground castings originally rejected for softness were found to be within the specified hardness on the ground surface. We believe that in the range of 1580 to 1640° F. the amount of iron decarburized by an oxidizing atmosphere is approximately one half of that decarburized by a reducing atmosphere containing hydrogen, other conditions being equal.

Another phenomenon which must be carefully watched in the heat treatment of cast iron is its lack of elasticity or recovery from expansion. This is particularly true of hollow cylindrical castings having walls of medium or thin section. If laid on the furnace hearth on their sides, the castings will be found to have elliptical bores after quenching. This distortion occurs in heating, due to a combination of unequal temperatures from top to bottom in the casting as it attains furnace temperature, plus pressure exerted on the casting by its own vertical component of weight. On bores a little over 3 in. diameter with $\frac{3}{4}$ -in. walls, the inside diameter was found to become 0.030 in. undersize on the diameter perpendicular to the hearth and at right angles to this diameter the dimension showed a corresponding increase.

The remedy is very simple. Merely stand the cylinder up vertically during heating.

Due to the great distortion caused by repeated or extended heating, castings having long holes, drilled or tapped, cannot be reheated for rehardening with much success. Axes of such holes originally parallel, may point in almost any direction after a second or third heat treatment.

One useful application of this type of growth is the salvaging of parts made undersize by grinding or machining. Repetition of the

original time cycle of heating was usually found adequate. Flat strips of cast iron $\frac{1}{4}$ in. thick, 1 in. wide, 3 in. long can easily be lengthened $\frac{1}{8}$ in. The expansion is more or less proportional to the length of time the part is held at the hardening temperature. While this action no doubt increases the porosity of castings so treated, we have never found it to produce deleterious effects. It will, however, cause cracks in thin sections of iron adjacent to holes.

H. H. LURIE
Metallurgist
Ross Gear and Tool Co.

Calorimetric Pyrometer Used in 1835

EDDYSTONE, *Penn.*—An interesting letter from E. B. Ashworth on an old calorimetric pyrometer was printed in METAL PROGRESS for May. It may be worth while to point out that this idea is much older than would be indicated by Mr. Ashworth's letter. I have in mind the report of a series of tests made by "Committee of the Franklin Institute of the State of Pennsylvania on the Explosion of Steam Boilers at the request of the Treasury Department of the United States" and printed in the *Journal of the Franklin Institute* over a period of years around 1835.

Of particular interest is Vol. 19 of the second Series, 1837. On page 86 is a description of such a pyrometer together with illustrations. This instrument was used by the Committee in high temperature tests of metals up to 1300 to 1400° F., at which temperatures they estimated that their results were within plus or minus 7°. An earlier reference to a device of this nature will be found in the *American Journal of Science*, Vol. 22, page 96, by Prof. W. R. Johnson.

This use of this device by the committee of the Franklin Institute is particularly interesting because it was necessary for them to determine, by tedious and careful experiment, the specific heat of the metal which was immersed in the water and of the water, and the latent heat of water vapor. A study of this data leads to an appreciation of the genius of these early experimenters, operating as they did under handicaps which would have given pause to less courageous and ingenious persons.

C. H. GIBBONS
Southwark Division,
Baldwin-Southwark Corp.

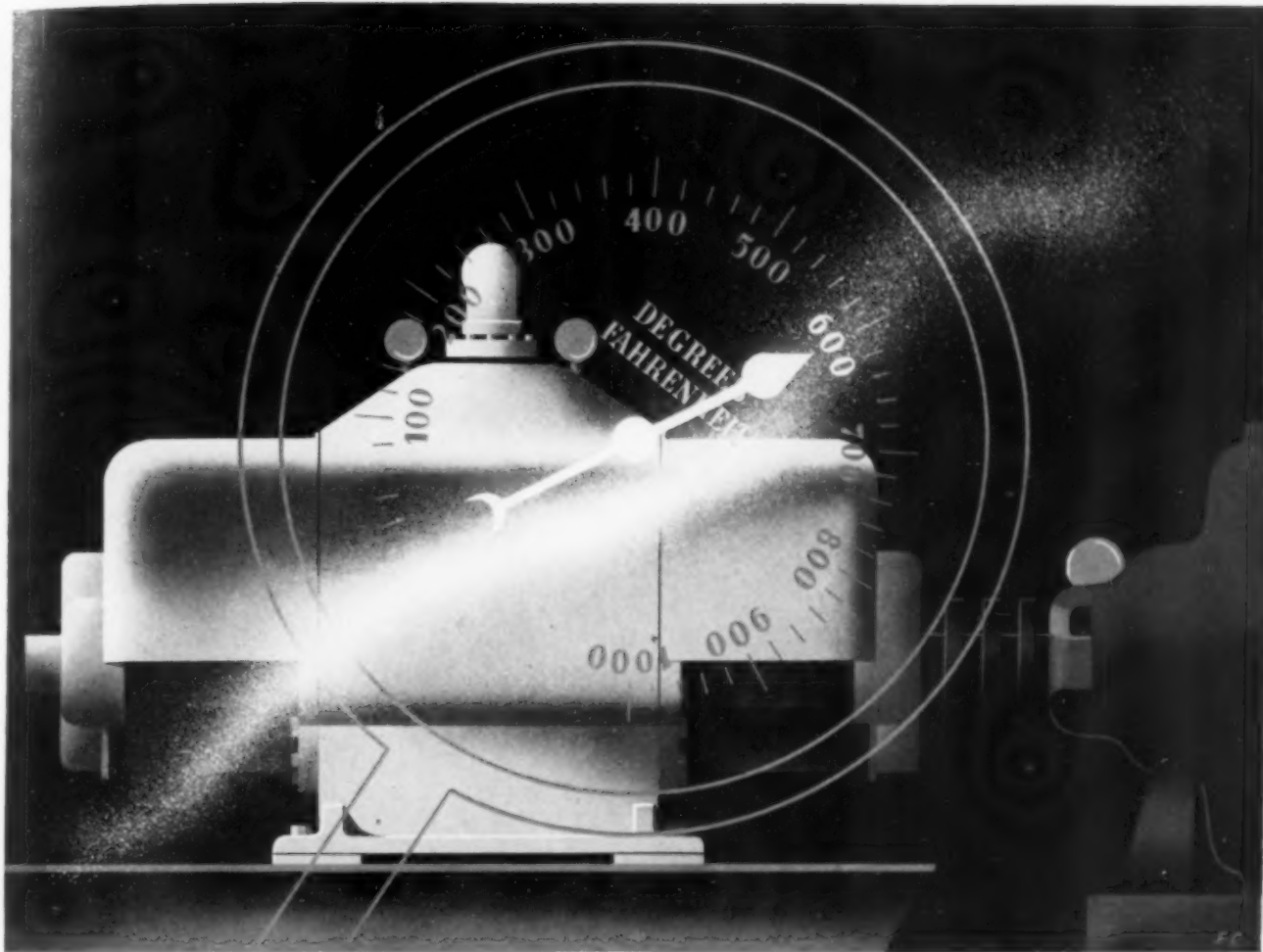
Slip Resistance and Cohesivity of Ferrite

RANDFONTEIN, *Transvaal*—The ordinary diagram showing stress and strain in a tensile test gives, no doubt, much information on the behavior of metals under direct load. Although the data are all quantitatively recorded, the appraisal is often more of a qualitative nature; that is, the weight to be placed on this or that factor is often left to judgment and experience. The writer believes that, beyond this, the stress-strain diagram—or even the test which notes only the yield and the breaking load—contains some very direct information of basic physical significance.

The test on soft steel shows two outstanding points, the yield point and the end point. The yield point indicates the tension necessary to induce noticeable slip in the test bar. It is very nearly true to say that the yield point indicates the tension necessary to *start* slip in the test bar. It is well known that slip commences in planes making an angle of 45° with the axis of the principal stress, and therefore the component of the direct tension active in producing slip is the yield stress divided by $\sqrt{2}$. This quotient will thus represent the shearing force per unit area needed to cause slip in a ductile crystalline individual imbedded in a matrix of similar individuals. I designate this the "slip resistance" of the steel.

With normalized carbon steels of fairly low carbon content and therefore showing a network of continuous ferrite, slip should commence within the most ductile portion of the aggregate, that is, in the ferrite. The slip resistance should therefore be largely independent of the actual carbon content as long as the pearlite does not grow so large in volume as to interrupt the ferrite matrix.

The end of the tension test gives the ultimate stress U . It is necessary to consider that this force acts on a reduced cross-section. If r represents the per cent reduction in area, then the actual breaking stress, reckoned in the direction parallel to the axis of the test bar, equals $100 U \div (100 - r)$. The latter clause is necessary because the actual break is not a plane at right angles to the axis, but is an irregular surface. If it is permissible to average this irregularity, we may assume a more regular pattern showing, on an axial section, a zig-zag contour where the small facets followed by the break are assumed to be inclined 45° to the (Continued on page 72)



BETTER MATERIALS FOR HIGHER TEMPERATURES

New developments bring new problems. The designing of an improved direct-drive steam engine, for oil-field service, necessitated the use of a material that would withstand continuous subjection to high steam temperature (550° to 600°F.).

The manufacturer adopted a Chrome-Nickel-Moly (0.50—1.00% Mo) iron for vital engine parts. Due to its Moly and Chromium contents, its high growth resistance assures maintenance of the close tolerances necessary to efficient engine performance.

This iron also has advantages from the standpoint of production costs. The castings are free from defects. They have fine grain in the heavy sections and satisfactory machinability in the light sections.

On the foregoing points alone, Moly irons warrant careful consideration. And there are many others, likewise attested in practice. Our book, "*Molybdenum in Cast Iron*," will show the way to more economical high-strength castings. It is free. Climax Molybdenum Co., 500 Fifth Ave., New York.

PRODUCERS OF FERRO-MOLYBDENUM, CALCIUM MOLYBDATE AND MOLYBDENUM TRIOXIDE

MOLY

Climax Mo-lyb-den-um Company

July, 1938; Page 67

Personals

Promoted: Alan Morris ☉, formerly research engineer, to position of chief metallurgist, Bridgeport Brass Co.

H. V. Beasley ☉ is now in charge of the new office of the Development and Research Division, International Nickel Co. at Pittsburgh.

J. J. B. Rutherford ☉, formerly of the research laboratory, U. S. Steel Corp., has joined the metallurgical staff of the Babcock & Wilcox Tube Co. as research metallurgist.

William J. Jabsen ☉, formerly field metallurgist for Bliss & Laughlin, Inc., has joined the sales department as sales representative in eastern Illinois, northern Indiana, and southern Michigan.

Made junior metallurgist at Gary Tin Mill of Carnegie-Illinois Steel Corp.: R. B. Gunia ☉, formerly an assistant metallurgist at Allegheny Steel Co.

Donald L. Clark ☉, for five years in the melting department, Atha Works, Crucible Steel Co. of America, has accepted a position in the melting department of Simonds Saw & Steel Co., Lockport, N. Y.

Awarded the Hennen Jennings Scholarship at Harvard University for graduate work in metallurgy: Francis T. McGuire ☉, graduate student at Notre Dame and metallurgist for Bendix Products Corp.

Fred A. Webber ☉, formerly metallurgist at Bantam Bearings Corp., is now metallurgist for Wickwire Spencer Steel Co. at the Goddard Works in Worcester, Mass.

Transferred by American Steel & Wire Co.: D. N. Blatt ☉, from chief inspector, Waukegan Works, to the Chicago district metallurgical department.

J. Halsey McKown ☉ has been made assistant vice-president, U. S. Steel Corp. of Delaware, with sales activities.

Promoted by Vernon-Benshoff Co.: Adam R. Kiefer ☉, from field metallurgist to precious metals metallurgist.


Larry E. Sherman ☉ has been appointed district sales manager for National Cylinder Gas Co. in Cincinnati.

Bruno Werra ☉, formerly metallurgist for the Werra Aluminum Corp. and Grey Iron Division of the General Malleable Corp. at Waukesha, Wis., is now metallurgist and foundry engineer for the Ebaloy Foundries, Inc., Rockford, Ill.

W. T. Schaup has been appointed as service engineer by Basic Dolomite, Inc., Cleveland.



New 48 page illustrated booklet entitled "The Story of Sulphurized Cutting Oils" now available to personnel of metal working plants. Please write to 2727 South Troy Street, Chicago, for your free copy using company letterhead and stating capacity.



Steelmen Who Never Saw an *Easy-Going* Inspector

Youngstown's Alloy Steel Division was launched in the depression. All users of alloy steel had their regular sources of supply, so Youngstown had to take the tough orders--the jobs that "couldn't be done." But Youngstown's crew did them--maintained uncanny uniformity of heats--met standards of precision considered almost impossible.

They never saw an easy-going inspector.... They've been born and raised on tough jobs, and that's why their steels, in the plants of user after user, set new and unequalled records for low percentage of rejects and high percentage of salable finished products.

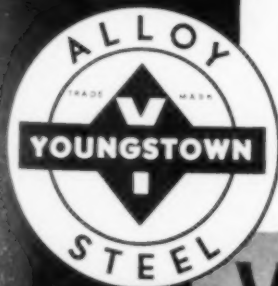
THE YOUNGSTOWN SHEET AND TUBE COMPANY

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Bars - Rods - Wire - Nails - Unions - Tie Plates and Spikes

4-3A



YOUNGSTOWN

Notes about contributors

A "major" in engineering materials and processes is held in high regard in the Mechanical Engineering department of Massachusetts Institute of Technology. It requires a broad engineering background coupled with specific training in physical metallurgy and strength of materials. The combination is found to be of particular service to metal fabricating industries. One such engineer who graduated in 1934 and is making good use of his training is **Francis G. Jenkins**. His first job was with Bethlehem Shipbuilding Corp. as assistant materials engineer, but since March of this year he has been with Eastman Kodak Co. in the material standards department. Both positions gave him a good opportunity to study the machining of copper alloys, and his observations, correlated with what he found in the recent literature, are contained in the leading article (page 34).

Engineer, author and inventor, **Albert F. Stuebing** has nevertheless devoted his entire career to railroading. Obtaining his mechanical engineering degree in 1911 (Cornell and University of Illinois), he started with the roads—the Boston and Albany, the Pennsylvania, and the Chicago, Rock Island & Pacific. Since 1923 he has been in the manufacturing end—with Bradford Corp., Ohio Steel Foundry Co., Par Car Corp., and for the past four years with United States Steel Corp. as railroad mechanical engineer. An interlude of six years as associate editor of *Railway Age and Railway Mechanical Engineering* trained him to facility with the pen—an outstanding attribute of his

Western Metal Congress paper starting on page 37. His special inventions include draft gears for railway cars and throttle valves for locomotives.

A registered racing driver who turned to metallurgy and engineering is **Robert G. N. Evans**. Adapting stock cars to racing in the years between 1910 and 1913, when the sport and the automobile industry were both still in their infancy, he first realized the need for correctly designed sleeve bearings—a problem which still holds his attention, as witness the article on page 43. Knowledge and observations on lubrication likewise picked up at this time served him in good stead later when he was service engineer with Paige Motor Car Co., Detroit. Following the War, during which he supervised a forge plant for the Army, he turned to consulting work, and in 1928 joined the staff of Bunting Brass & Bronze Co. in Toledo, Ohio, as engineer in charge of research.

Willis McGerald Peirce attended Penn State, University of Illinois, and Yale, earning a master's degree in metallography from the latter university. In his 20 years with New Jersey Zinc Co. he progressed successively from metallographer, to chief, Metal Section, Research Division, to chief, Metal Research Division, to assistant chief of research (1937), and finally chief of research (1938). He is the inventor and patentee of various zinc-base alloys for rolling and for die casting, and is the author of numerous papers and articles relating to physical metallurgy of zinc.

Albert F. Stuebing



Robert G. N. Evans



Francis G. Jenkins



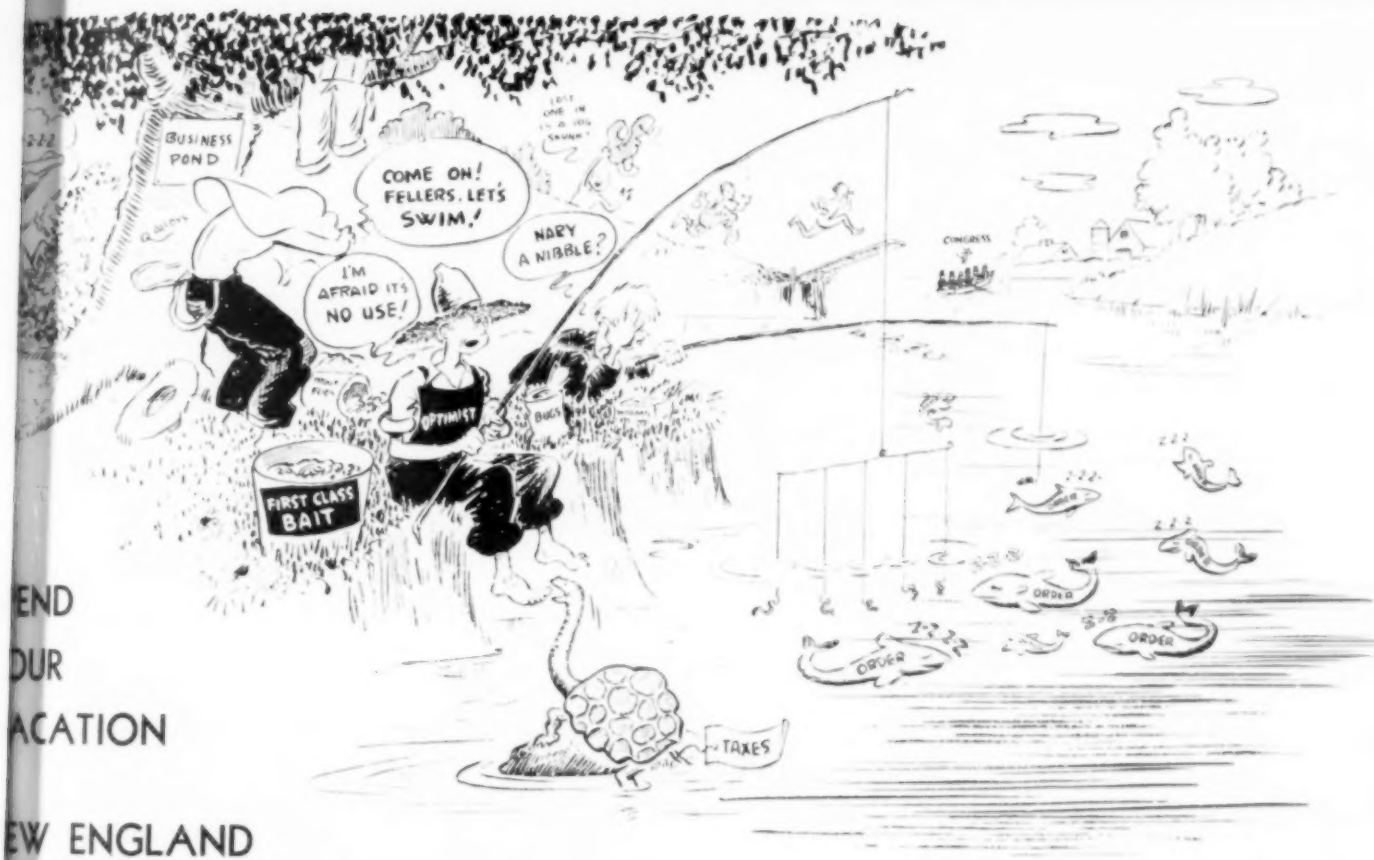
Willis M. Peirce



ALLOY

Bright Spot in Metal Progress

PROGRESS



**"THE
FISH
AIN'T
BITIN'
—SO—
LET'S
GO
SWIM
-MIN'!"**

DOWN upon the Sangamon River, when they weren't bitin',—we kids quit fishin' and went swimmin'. The ole swimmin' hole felt mighty good in the "Dog Days" of July and August, too! Of course we used to come back at night with lanterns and spear a few, or maybe "Hog" catfish with our bare hands under the willow roots.

EVER been horned by a big "Cat"? Those Y.M.C.A. swimmers miss a lot! Seems like the world is gettin' sissier and sissier! (The D.A.C. Pool is 78".)

THE General Alloys Gang is going to keep cool through the Dog Days with the Atlantic Ocean to play in. If you can break away from the rush of business, come to Boston and join us. When a Marblehead waiter asks—"How did you find the crab-meat, Sir?"—that Detroit snitty, "I'm a Detective," falls flat, but you must see for yourself.

HARD as this stuff may be to read, it's a lot harder to write—and I'm getting a real break too, by cutting out Alloy Progress—or hob-tailing it right up to the solenoids—for July and August. That's a real vacation!

WERE starting this summer being GUESTS, just to get in training for a bit of Hosting. "Tony" Fokker has asked us to the launching of his new tri-hub-screw Motor Yacht "Q.E.D."—a 2200 hp, aero-engineered marine skyrocket with hot and cold running door knobs, refrigerated ostermoors, and Psycho-marine control. His mother will christen

"Q.E.D." by radio-telephone. The first Dutch boat built in America, she is Fokker's contribution to American recovery, and to marine engineering.

"Q.E.D.'s" bottom anchor, nesting into her keel, and her deck hardware is SEA STEEL, the Super-Stainless-Steel product of General Alloys Marine Department, which is also complete equipment on the new "Rambler V," sea going packet of Andy Langhammer, popular president of Chrysler-Amplex. We'll describe "Q.E.D." with photos next issue.

BETWEEN dips in the W.K. Atlantic, there's a little matter of following through twenty-three patents pending, filling about fifteen more on a flock of new heat-treating containers, trays, retorts and furnace mechanism. Technical progress based on research and development is the only depression-buster known to man.

THERE is also the problem of revamping manufacturing processes and equipment to new standards of precision, and the doubling of plant capacity to meet the coming boom, for, whether you call it a "shot-in-the-arm," or a "kick-in-the-pants," we are heading for much better business. Meanwhile, go take a swim for yourself, before the orders swamp you.

"THE Swiss Cheese has all the holes, while the Limburger needs all the ventilation," reads a sign on the Lincoln Highway, just another sign of advanced thinking, or political bacteria, from which, we are inclined to believe, the patient is slowly recovering. H.H.H.

SERIOUSLY

IF you have time to seriously consider improvement in furnace mechanism and in furnace controlled alloy economy, you will profit by giving a G.A. Field Engineer an opportunity to present—for your consideration—the following definite and undisputable contributions to the art.

SPIRALINK conveyor hearth mechanism for continuous furnaces. The simplest, strongest, and lowest operating cost "Belt-Type" conveyor of outstanding mechanical superiority—Your Furnace Builder will supply it.

SMOOTH-SCREW Furnace Conveyor which moves trays individually or collectively without compression, is self emptying, outstanding economies. No other mechanism survives logical comparison. Your Furnace Builder will supply it.

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IF you are going to buy a mechanical furnace, we will gladly meet with your furnace builder in your office, prove our statements, guarantee our product.

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CARBURIZERS

CHAR PRODUCTS COMPANY
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Slip and Cohesivity

(Cont. from page 66) axis. The true area of the break would then be obtained by multiplying the original section A by $\sqrt{2}$. Furthermore, the pull exerted acts only with the fraction $1 : \sqrt{2}$ in a direction perpendicular to the small assumed planes of fracture. Taking account of all these circumstances, the actual force, per unit area needed to separate the (stretched) metal by pulling it apart will equal $50 U \div (100 - r)$. We may call this quantity the "cohesivity."

In straight carbon steels with a continuous phase of ferrite the cohesivity should be almost independent of the carbon content, because we may expect the break to occur entirely in the ferrite, the weakest constituent. Data for the three carbon steels in the table are scaled from

	CARBON STEELS			3½% NICKEL
	0.10% C	0.20% C	0.30% C	0.20% C
Yield point, Y	33,000	37,000	42,000	55,000
Slip resistance, $Y \div \sqrt{2}$	23,500	26,000	29,500	39,000
Ultimate stress, U	50,000	63,000	77,000	85,000
Reduction of area, r	72%	63%	54%	65%
Cohesivity, $50 U \div (100 - r)$	89,000	85,000	84,000	120,000

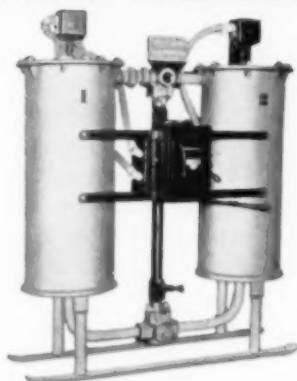
Fig. 47 of "Alloys of Iron and Carbon," Vol. II, by Frank T. Sisco, a diagram averaging the tensile properties of normalized acid open-hearth steels, as they vary with carbon content. The slip resistance slightly increases with the carbon content, in conformity with the known fact that the yield point of mild steels is but gradually raised as the carbon goes up. The continuity of the ferrite phase for these three normalized steels would be quite evident under the microscope.

The addition of an alloying element can affect both the slip resistance and the cohesivity of ferrite. Data for a 3½% nickel casehardening steel in the annealed condition are taken from Metals Handbook, page 1413, and the results are shown in the last column of the table. The presence of the alloying element is shown especially in the cohesivity. The structure of this type of steel, low in carbon, has also a continuous ferrite phase in the annealed condition.

O. A. TESCHE

Metallographic Research Laboratory
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The Driver-Harris pattern warehouse, close by the foundry, contains upwards of 45,000 pieces—an inventory value of over half a million dollars. Some are exclusive patterns of customers. But most of them are stock patterns available to every D-H customer.

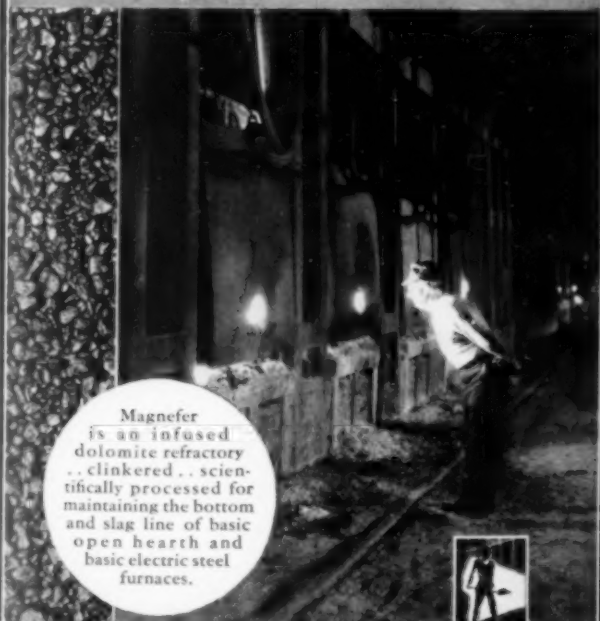
All of which represents a pattern-making, molding and casting experience second to none in the nickel-alloy industry. That is why NICHROME* and other D-H castings include that *something extra* so sought by experienced users.

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NICHROME

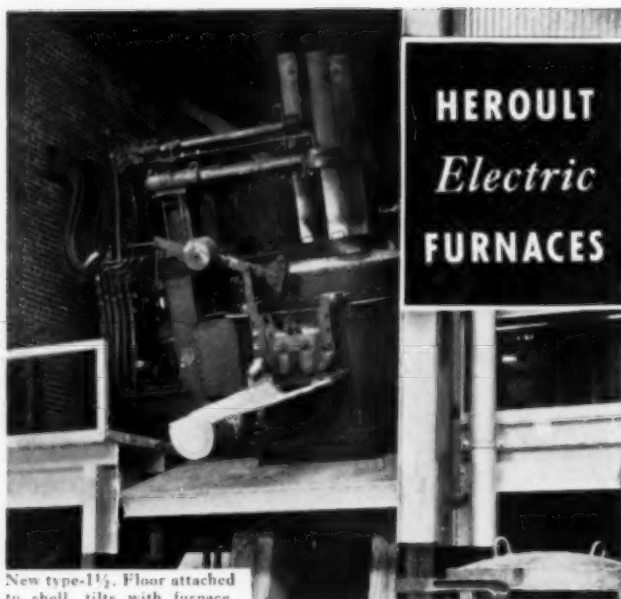
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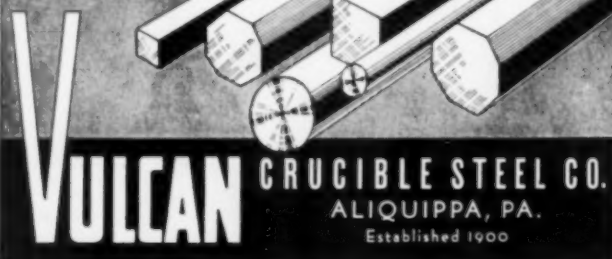
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Established 1900

Aircraft

(Continued from page 42)

While steel spars of this type enable the designer to utilize the entire strength, local instability has never been entirely overcome, either in the built-up metal spar, or the thin metal skin loaded either in compression or shear.

Now the stress which will cause buckling in the sheet is in general proportional to the elastic modulus of the material, to the square of its thickness, and inversely to the square of its minimum free width. Thus, if the superficial dimensions and the weight of the structure are fixed, the buckling stress is proportional to $E w^2$, so that, assuming the modulus E to be roughly proportional to the specific gravity w for all materials, the lighter material is again the better. In the monocoque fuselage no real advantage can be taken of any improvement of strength of the material above the buckling stress; what is required is a material having a higher modulus of elasticity and a lower density. In the wing, on the other hand, whether a spar or a box form of construction is used, instability can usually be avoided, and in that case full advantage can be taken of any increase in the intrinsic strength of the material. However, a high strength may be rendered useless by a low 0.1% proof stress, since aircraft are usually required to carry three quarters of the full factored load without permanent deformation. Ultimate strength is really the criterion for complete collapse and is normally more than $1\frac{1}{3}$ times the proof stress.

In the light metals there has been a steady development of the sheet alloys for stressed skin construction, but the outstanding feature is the replacement of rolled, drawn or composite sections by extruded shapes. Corrosion has been largely solved by the introduction of alloys clad with purest aluminum; even with them it is still considered desirable to use the anodic process for its additional protection and, for marine work, a final greasing with a lanoline solution is strongly recommended, while a cellulose finish with two coats of undercoating and two finishing coats provides a good additional protection.

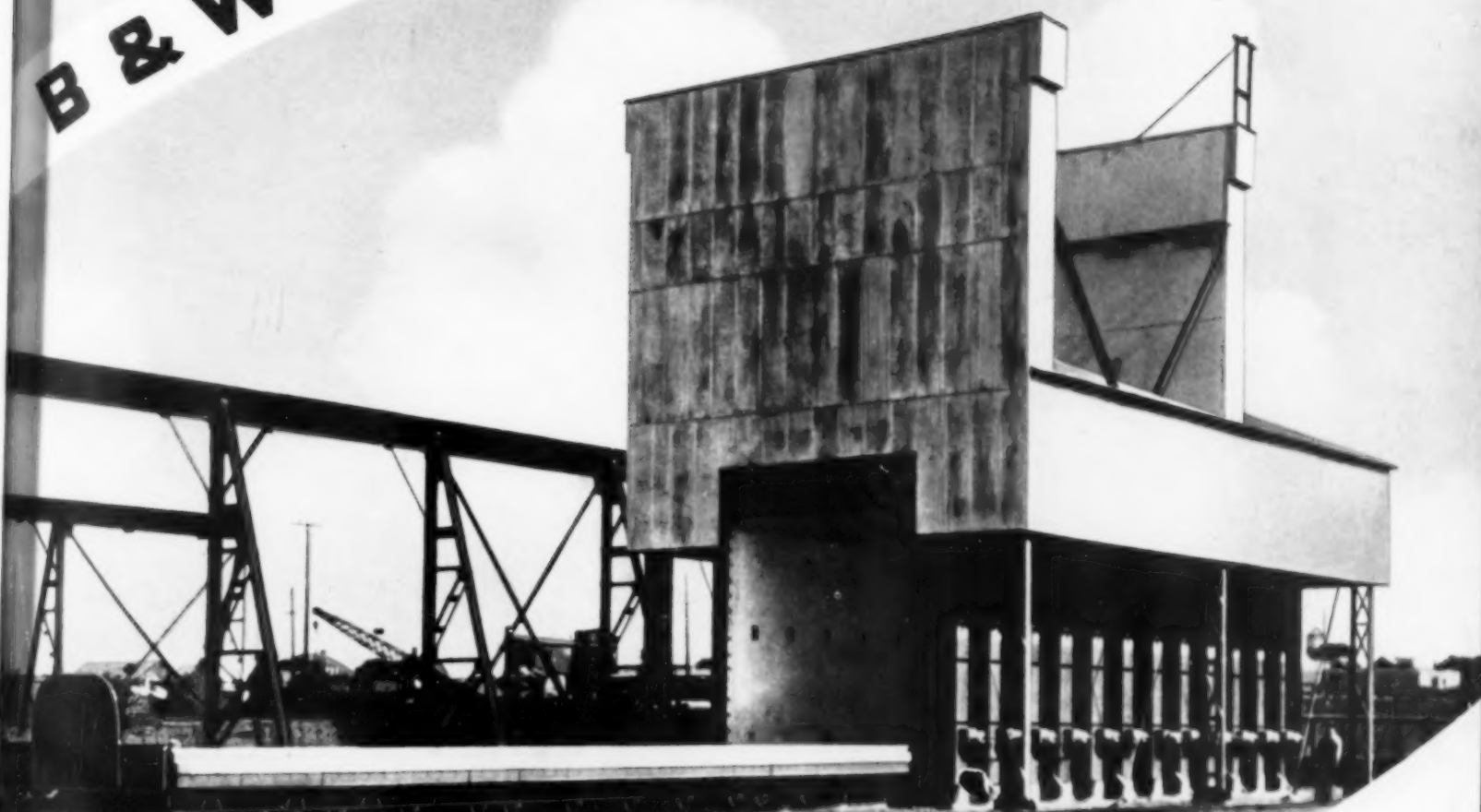
Ease in manufacture is an important aspect; hence the use of alloys where strengthening by precipitation hardening can be delayed until fabrication is completed and then induced by a very mild reheating. Light metal construction is mostly riveted at the present time, and any method by which the plates can be brought to the machine, instead of riveting in place, offers an advantage. The same consideration will also apply to welded construction, for which there is undoubtedly a great future.

(Continued on page 78)

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■ Aircraft

(Continued from page 76)

Laminated wood is a very interesting material used by deHavilland. It consists of two sheets of 3-ply wood separated by a layer of Balsa wood. Much study has also been given to other combinations, with or without fabric inserts or previous impregnation, cemented together under pressure. Resulting specific gravity ranges from about 0.8 up to a limit of 1.4 (aluminum alloy is 2.8). These materials show to advantage under pure compression, the ultimate strengths being higher in proportion to specific gravity than that of aluminum and steel alloys; on proof stress they do not show up quite so well. In one instance the Balsa wood layer was replaced by vulcanized expanded rubber, the latter being very light and free from moisture absorption, mold and fungus attack possessed by the Balsa wood and which make necessary such careful sealing of joints and free surfaces. In an experimental wing section of this construction a very good strength-weight ratio has been obtained under test. Similar tests are also proceeding on a certain type of plywood which has an inner layer of duralumin.

Laminated wooden construction lends itself very easily to strengthening by reinforcement at sections and ends subjected to heavy shearing or bearing forces; this can be achieved by fabric inserts introduced between the laminations. A spar may now be produced having selected properties of strength and density, varying along its length. Experimental spars of vacuum-impregnated and compressed wood have been built up to 60 ft. in length; such spars are not difficult to produce; neither is their actual cost uneconomic.

The idea of aircraft structures entirely made of molded plastic is most attractive. The materials offer the advantages of extreme surface smoothness, stability, low water absorption, and ease of mass production. But although a plastic non-stressed fuselage covering actually appeared as early as 1919, it is believed that no airplane made of plastic has yet been seen in flight.

Experimentation on wings is now proceeding, utilizing a material made from a cellulose fluff impregnated with a phenolic resin which can be molded into a required form under a pressure of 2 tons per sq.in. at 300° F. Its ratio of modulus of elasticity to specific gravity is 1.4×10^6 , as compared to 2.9×10^6 for reinforced wood and 3.6×10^6 for aluminum alloy. The stiffening ribs are molded integral with the skin, and the units are held together by screws without need of metal inserts. It is estimated that complete basic molded panels for a single-engined scout can be produced in 82 hr.